Fraser River Estuary Monitoring

Report on the 1988 Fish Monitoring Program

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British Columbia

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REPORT ON THE 1988
FISH MONITORING PROGRAM

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SUMMARY

Fish were collected from three sites in the lower Fraser River during August 1988 by P.A. Harder and Associates. As was possible, muscle tissue and livers were dissected and submitted for separate analysis to Analytical Services Laboratories. Analyses performed included metals, PCBs, chlorophenols, PAHs, phthalate esters, and organochlorine pesticides. As possible, results from this survey were compared to two earlier studies, one in 1980 and a second in 1972/1973. The data are also evaluated as appropriate with regard to water quality objectives for PCBs and chlorophenols in fish muscle tissue, and compared to data for other non-industrial sites in British Columbia.

Differences in concentrations among species appear to be randomly distributed. Fish collected from the Barnston Island site, upstream from many sources in the Lower Mainland, do not appear to be any less contaminated than fish from the lower river reaches. It is recommended that a similar study with appropriate controls be undertaken in about five years time.

METALS

Analytical detection limits used in the 1988 survey were considerably lower than used in the 1980 or 1972/1973 surveys. Although fish from 1972/1973 had been retained and analyzed prior to the 1980 survey to confirm that the results from the 1972/1973 could be compared to 1980, fish kept from 1980 were lost in subsequent years so that comparisons could not be made between the 1980 survey and this one. Thus comparisons of the 1988 data to those from previous surveys must be made with caution, and the quality control data from this survey become highly important.

In terms of accuracy of results for both liver and muscle tissues, it is important to note that most measurements made by the laboratory on certified specimens were either within the certified range of values or only slightly lower than the range. Exceptions to this were for mercury in livers, which was reported as not detectable (detection limit is well below the certified range of values), and one lead measurement in liver which was slightly higher than the certified range. Duplicate analyses of split samples were generally within 20% of each other.

Other quality control measurements were made with regard to possible contamination of the samples during the digestion process. Usually, metals could not be detected, although at least once, some slight contamination was noted with chromium, copper, iron, lead, nickel and zinc in muscle tissues, and iron and nickel in livers. Contaminant levels were so low on these occasions that it was not deemed necessary to make corrections to the data on this basis.

Due to the fact that starry flounders and redside shiners were not filletted, considerable problems were encountered in preparation of the samples. The laboratory analyst suspects that for these two species, contamination occurred for chromium, iron, molybdenum, and nickel. Therefore, these metals were not discussed with respect to these two species.

Metal concentrations in fish tissue can vary significantly within the same species captured at different sites or among different species from the same sites. In this survey, similar variability of data as examined by the F-test, and statistically similar mean values as examined by the Student's t-test, were found to be present more in the data on livers than on muscle tissue.

When comparing mean values in muscle tissues for the same species between at least any two sampling sites, statistically different values occurred for four metals in largescale suckers, and two metals each for peamouth chub and northern squawfish. Copper in largescale suckers and northern squawfish was lower in the North Arm than at the other two sites, and this was the only apparent trend for these data. In livers, different values were found only for copper in largescale suckers and northern squawfish.

As expected, considerably more variation in data and significantly different mean values were noted when different species at the same site were compared to each other. This was evident for both muscle and liver tissues, and verifies that the different species had different amounts of the metals.

Higher concentrations of metals were generally found in liver than in muscle, as was the case for the 1980 survey. Exceptions to this, also found in the 1980 survey, were for chromium and mercury. Higher mercury levels had been reported in liver than muscle for fish from Pinchi Lake where mercury tailings have been deposited. This leads us to conclude that there does not appear to be a major anthropogenic source of mercury to the lower Fraser River.

In comparing metal levels in muscle tissues for five metals which can be compared among the 1972/1973, 1980 and this survey, values generally are similar or declining for copper, mercury, and zinc. For iron and manganese, no trend is apparent.

In comparing mean metal concentrations found in Fraser River fish with those found in fish (different species) from uncontaminated lakes in British Columbia, it can generally be stated that concentrations in Fraser River fish were lower or of approximately the same magnitude. There were some exceptions to this general statement for a few species for some metals, and for all species for arsenic. However, it does not appear that present metal levels in Fraser River fish are different from what generally would be expected in other less industrialized areas.

CHLOROPHENOLS

The water quality objective for chlorophenols in muscle tissue in the Fraser River downstream from Kanaka Creek is a maximum of 0.1 µg/g (wet-weight), as the sum of tri-, tetra-, and pentachlorophenol. This objective was achieved for all fish muscle tissues analyzed in this survey.

Trichlorophenol concentrations in muscle tissue from peamouth chub from the Main Stem were significantly higher than those found in largescale suckers or northern squawfish from the same site. In the North Arm, the mean trichlorophenol concentration in muscle tissue from northern squawfish was significantly higher than found in largescale suckers from the same site.

In muscle tissue samples, tetrachlorophenols were not detected.

Pentachlorophenol concentrations in muscle tissue of all species were low, with mean values of 0.001 µg/g or 0.002 µg/g. Chlorophenol concentrations in muscle tissue appear to have been reduced considerably since the 1980 survey.

Chlorophenols concentrations in livers were difficult to compare to those in muscle tissues since the detection limit in livers was considerably higher. However, when maximum values in each were compared, it is speculated that all three chlorophenols measured may be accumulating in livers.

PCBs

The water quality objective for PCBs in muscle tissue of a maximum of 0.5 µg/g (wet-weight) was achieved for all samples analyzed in this survey. The mean PCB concentration in muscle tissue in northern squawfish from the North Arm was significantly lower than found in the same species from the Main Stem or Main Arm.

PCB concentrations in muscle tissue appear to be lower than were recorded in 1972/1973 for the same species at the same sites. However, too few analyses were conducted in the earlier survey to make meaningful comparisons. Values for 1988 are also lower than measured in 1980.

The highest PCB levels by species except starry flounder were in fish from the North Arm. Of the two species with a sufficient data base, this was also confirmed by statistical test for mean values in largescale suckers.

PHTHALATE ESTERS

Laboratory sources of phthalates were considered responsible for individual phthalate concentrations up to a maximum of about 0.046 to 0.11 µg/g in fish muscle tissue. In liver, contamination did not seem to be as evident, likely due to the use of considerably higher detection limits. Nonetheless, contamination from laboratory sources of diethyl phthalate (0.35 µg/g) and bis (2-ethylhexyl) phthalate (0.61 µg/g) was measurable. In this study, values above these concentrations were considered to be indicative of possible real contamination while those below these levels were considered as at being non-detectable levels.

Di-n-butyl phthalate and butyl benzyl phthalate were evident in the largest number of species and individuals of each species in muscle tissue. Conversely, dimethyl phthalate was detected in the fewest number of species and individuals.

Within species, levels of both butyl benzyl phthalate and bis (2-ethylhexyl) phthalate in fish from the Main Stem were found to be significantly higher than in fish from the Main and North Arms, and the Main Arm, respectively.

For muscle tissue, it appears that differences in data variability or mean values are random, and that no apparent trend exists for phthalate esters.

In livers, the following phthalate esters were found in some species at measurable levels; diethyl, di-n-butyl, butyl benzyl, and bis (2-ethylhexyl). This implies that some phthalate contamination of fish livers is taking place. Generally, there was an insufficient data base available to determine statistically if phthalates were accumulating in livers. However, it is suspected that di-n-butyl, butyl benzyl, and bis (2-ethylhexyl) phthalate may be accumulating.

PAHs

PAHs were measured in muscle tissue from fish only from the North Arm of the Fraser River, an area which would receive considerable stormwater runoff.

PAHs were found in considerably more liver samples than muscle tissues. The detection limit for livers was five times higher than for muscle tissues. Therefore, PAHs are likely accumulating in livers.

Naphthalene was the only PAH detected often enough in fish livers to enable a statistical comparison. Generally, there was no significant difference within a species or between species from the Main Arm and North Arm.

ORGANOCHLORINE PESTICIDES

The most commonly measured organochlorine pesticides in muscle and liver were alpha- and gamma- chlordane, dieldrin, DDT, DDD, and DDE. Of these, only DDE was detected frequently enough at all sites so that some comparisons could be made. Most mean values in muscle and liver for the same species were not different between sites, except in muscle for northern squawfish from the North Arm which was significantly higher than those from the Main Arm.

For different species at the same site, the mean concentration of DDE in muscle of largescale suckers from the Main Arm was significantly lower than found in northern squawfish or peamouth chub.

Concentrations of organochlorine pesticides in muscle tissue appear to be lower in comparison to values measured for fish captured in 1972/1973. These compounds were not considered to be a serious environmental problem at that time, and thus are likely even less so now.

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1. INTRODUCTION

On April 1, 1986, a five-year agreement was concluded between the Fraser River Harbour Commission and the B.C. Ministry of Environment. The agreement related to carrying out monitoring in the Fraser River Estuary area, based on a report prepared by the Working Committee on Fraser River Estuary Monitoring (1984). The estuary area under study is from Kanaka Creek downstream.

Monitoring during 1988 was directed towards determining the quality of fish in the Fraser River Estuary system. Samples were collected in August, 1988 from the riverine section of the Estuary (see Figure 1).

The purpose of the monitoring was:

1. To determine levels of metals and organic contaminants in fish from the riverine section of the Fraser River Estuary.
2. To determine variability between sample sites.
3. To determine the degree to which values in fish meet provisional Water Quality Objectives for this section of the estuary (Swain and Holms 1985).

1.1 SITE SELECTION

Three sites, one in each of the Main Stem, Main Arm, and North Arm were used for the collection of varying numbers of replicate fish samples. These sites are MS-1, MA-2, and NA-2, respectively, located as described in Swain (1986). The sites are shown in Figure 1.

1.2 PROVISIONAL WATER QUALITY OBJECTIVES

The B.C. Ministry of Environment is currently establishing provisional water quality objectives on a site-specific basis. One area where such Objectives have been published is for the Fraser River from Kanaka Creek to the mouth.

Provisional objectives which are applicable to the fish examined in this survey are (Swain and Holms 1985):

Chlorophenols: 0.1 µg/g (wet weight) maximum in fish muscle
PCB : 0.5 µg/g (wet weight) maximum in fish muscle

Existing chlorophenol levels in fish muscle were used in setting a provisional Objective at 0.1 µg/g (wet weight). Levels of this magnitude occur in fish in relatively uncontaminated parts of the Fraser River and other rivers in Canada.

Polychlorinated biphenyls (PCBs) can enter the river channels through urban stormwater runoff, sewage discharges and have been associated with industry on the North Arm. Objectives were therefore proposed to limit a build-up of these substances. The objective of 0.5 µg/g (wet weight) in fish muscle was set to minimize the passage of PCBs along the food web. It is met generally in parts of the river which are relatively uncontaminated by PCBs (Swain and Holms 1985).

Both of these objectives are partly empirical but also conservative. If achieved in the short-term, they are expected to prevent any harmful effects to aquatic life or users of aquatic life.

2. MATERIALS AND METHODS

2.1 FIELD METHODS

Fish were collected by P.A. Harder and Associates Ltd. using a 45 metre gill net with variable mesh panels.

At each of the three sites (MS-1, NA-2, MA-2), minimum sample goals were to collect ten samples of each of threespine stickleback, peamouth chub, largescale sucker, northern squawfish, and sculpin. As well, sturgeon and salmonids were to be collected as opportunity permitted.

All specimen were identified to species, weighed and fork length measured. Fish were dissected if possible and either whole fish or muscle tissues, plus livers were packaged in glass bottles for organics analysis or plastic tissue cups for metals analyses. These were stored on-ice in the field and frozen on the day of collection. Frozen samples were delivered to the laboratory on a weekly basis.

2.2 SAMPLE PREPARATION

The samples were received by Analytical Services Laboratories Ltd. (ASL) as frozen prepared tissue which had been dissected by P. Harder and Associates. Prior to subsampling, each tissue was homogenized using a tissue blender. To avoid cross contamination, the blender was rinsed between each sample with the following series of solutions:

- Deionized Water
- 2% Nitric Acid
- Acetone
- Deionized Water

To avoid repeated freeze/thaw of the samples, each homogenized tissue sample was divided into four separate aliquots, one for each analysis group listed in Sections 2.3.1 to 2.3.4. All tissues were stored frozen until analyzed.

2.3 ANALYTICAL METHODOLOGY

2.3.1 METALS

All samples were analyzed in accordance with documented methods using state-of-the-art instrumentation and laboratory apparatus. Extensive quality assurance measures (see Section 2.8) were taken to ensure the data produced were of a known and acceptable level of precision and accuracy.

The samples were analyzed in accordance with procedures outlined in the U.S. EPA 301(h) analytical protocols. Specifically, a representative subsample of homogenized tissue was digested using a combination of nitric and perchloric acids. The resulting extract was analyzed for the metals of interest using various optimized atomic absorption and emission techniques. The detection methods are summarized as follows:

Element	**Instrument Detection Mode**
Cd, Pb, Cr, Mo, Ni	Perking Elmer Model 2380 dual beam spectrophotometer equipped with automatic background correction and HGA-400 Graphite Furnace.
As	Perkin Elmer Model MHS-20 hydride generation system coupled to a Model 2380 AA.
Cu, Fe, Mn, Mg, Zn	Perkin Elmer Plasma 40 Inductively Coupled Argon Plasma Spectrograph.
Hg	Pharmacia Model U.V. mercury monitor equipped with a 30 cm absorption cell.

2.3.2 CHLORINATED PHENOLS

A representative portion of each sample was extracted using a modification of the procedure published by Tetra Tech (1986). This procedure involved the soxhlet extraction of the sample with acidified hexane/acetone followed by solvent partitioning. The crude extract was then cleaned-up using Sephadex QAE-A25 ion exchange resin (Renberg, 1974). The resulting extracts were derivatized using acetic anhydride and analyzed by capillary gas chromatography with electron capture detection.

2.3.3 POLYCHLORINATED BIPHENYLS, ORGANOCHLORINE PESTICIDES AND PHTHALATE ESTERS

A representative portion of each sample was extracted using a modification of the procedure published by Tetra Tech (1986). This procedure involved the saponification of the sample with ethanolic potassium hydroxide followed by solvent partitioning into iso-octane. A clean-up procedure using silica gel column chromatography (EPA Method 610, U.S. EPA 1984) was then employed. The resulting extracts were analyzed by capillary gas chromatography with electron capture detection.

2.3.4 POLYCYCLIC AROMATIC HYDROCARBONS

A representative portion of each sample was extracted using a modification of Procedure 21.001 (AOAC, 1984). This procedure involved the saponification of the sample with ethanolic potassium hydroxide followed by solvent partitioning into iso-octane. This crude extract was then subjected to a clean-up procedure using phosphoric acid and solvent partitioning between iso-octane and dimethyl sulfoxide. A further clean-up procedure using silica gel column chromatography (EPA Method 610, U.S. EPA 1984) was also employed. These clean-up procedures have been found to effectively remove unwanted hydrocarbons which could potentially interfere with the analysis. The resulting extract was then analyzed by capillary gas chromatography with flame ionization detection.

2.3.5 MOISTURE CONTENT

A representative portion of the sample was dried to a constant weight at 105°C. Moisture was determined gravimetrically by determining weight loss upon drying.

2.3.6 QUALITY ASSURANCE/QUALITY CONTROL

The following is based upon information provided by ASL Laboratories. Extensive quality assurance measures were taken to ensure that the highest level of precision and accuracy was maintained. All analyses were performed using accepted procedures and included the concurrent analysis of reagent blanks, sample duplicates, analyte spikes and certified reference materials (where available).

Quality control samples analysed with the 104 fish muscle tissue samples were:

Metals - Digestion Blanks (n=8), sample duplicates (n=22), and certified reference material (CRM) (n=8) consisted of 4 - DORM-1 (Dogfish muscle) and, 4 - TORT-1 (Lobster tissue). Both of these were available from the National Research Council.

Organics - Reagent (extraction) blanks (n=10), sample duplicates (n=16), and analyte spikes (n=10)

For metals, only trace amounts of some metals (Cu, Fe, Pb and Ni) were detected in the digestion blanks, indicating good contamination control. Further discussion is included for each characteristic in the appropriate section. Where discussion relates to precision of duplicate analyses, the percent difference between values is calculated as the difference divided by the smaller of the two values, which would produce numbers which seem less precise than if the average or maximum values were used in the calculation.

For the organic analysis, only phthalates were detected in the extraction blanks. Considering the number of phthalate sources, their relative abundance and mobility, this was not unexpected. Results of the duplicate analyses demonstrated an acceptable level of precision. The spike and recovery data demonstrated acceptable levels of accuracy for all compounds.

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3. RESULTS AND DISCUSSION

Based upon previous fish sampling programs, it was estimated that the sample quotas could be met by assuming that five days were to be spent collecting fish from each site. Sample quotas were met for four of six target species at MacDonald Slough (NA-2) and five of six species at Ewen Slough (MA-2). Full quotas were not met for any of the target species at the Barnston Island Site (MS-1); however, reasonably complete collections were obtained for largescale suckers, squawfish, and peamouth chub while a complete set of redside shiners was obtained.

Total number of samples collected were as follows:

	Number (#) and Weight (g) of Samples Collected								
SPECIES	McDonald Slough (NA-2)			Ewen Slough (MA-2)			Barnston Island (MS-1)		
	#	Wt	L*	#	Wt	L*	#	Wt	L*
Largescale Sucker	12	1337	11	12	795	12	5	288	5
Northern Squawfish	14	1479	12	12	932	12	11	458	11
Peamouth Chub	13	970	13	12	645	12	13	360	10
Starry Flounder	5	236	5	175	635	2	0	0	0
Threespine Stickleback	637	155	0	1	7	0	0	0	0
Staghorn Sculpin	13	440	12	12	489	10	1	24	1
Redside Shiner	0	0	0	0	0	0	10	591	0
Other**	2	26	0	0	0	0	0	0	0
	696	4643	53	224	3503	48	40	1721	27

L* denotes liver samples. ** not analyzed

These species could generally be classed as "bottom feeders", consuming bottom invertebrates as well as fish eggs and insects. Some, such as redside shiners, threespine stickleback, and northern squawfish will also eat other young fish.

The following monitoring effort was used to obtain the samples:

	Beach Seines 30 m nets	Gill Nets Overnight 45 m panels	Minnow Traps # Set
McDonald Slough (NA-2)	18	10	20
Ewen Slough (MA-2)	13	8	20
Barnston Island (MS-1)	16	8	0

All results in the following are discussed on a wet-weight basis, unless otherwise noted. Conversion of maximum and minimum values from a dry-weight basis to wet-weight basis used the actual moisture content for the speciman in question, but average values were obtained by converting the calculated average value on a dry-weight basis to wet-weight using the average moisture content for all samples from that site (Table 1).

When at least one-half of the results are above the detection limit, average values and corresponding standard deviations have been calculated. In cases where values are less than the minimum detectable concentration, the absolute value of the detection limit has been used to calculate average concentrations. If more than one-half of the results are below the detection limit, average values and standard deviations are not calculated since there is too much uncertainty with so many values less than detection.

Values less than detection are referred to as "ND" in the summary tables. The detection limit is indicated for each characteristic under the title for that characteristic (e.g., ND: 0.01).

3.1 METALS AND METALLOIDS

The trace metals are presented in alphabetical order in the following sections. Results for fish muscle are summarized in Table 2 while those for liver samples are summarized in Table 3. All data for individual samples are included in the Appendix. Discussion of metals is limited to those considered to be priority toxicants.

In the process of preparing (digesting) the fish for analyses of metals, it is possible for some contamination to occur. For this reason, eight blank samples were analyzed for all metals in flesh, and four were analyzed in livers. For contamination to be present, measurable quantities would be present in these digestion blanks.

In the muscle tissue analyses, the following was detected in the digestion blanks:

Metal	Number of Samples of 8 with Detectable Concentrations	µg/g wet-weight Measured Concentration(s)	µg/g wet-weight Average Concentration for 8 samples
Cr	1	0.01	0.0012
Cu	1	0.06	0.0075
Fe	1	0.35	0.044
Pb	2	0.02, 0.02	0.005
Ni	3	0.01, 0.01, 0.01	0.0038
Zn	3	0.07, 0.06	0.016

Since contamination due to digestion was either not detectable or very low, corrections were not made to the data values reported by the laboratory.

In the liver analyses, only iron and nickel were measured in digestion blanks. Iron was measured in 3 of 4 samples (0.22, 0.22, and 0.33 µg/g) at an average concentration of 0.19 µg/g. Nickel was measured in 2 of 4 samples (0.05 µg/g each time) at an average concentration of 0.025 µg/g. Since contamination due to digestion was usually not detectable or low, corrections were not made to the data values reported by the laboratory.

Comparisions are made in the following sections to surveys conducted in 1980 and 1972/1973. Values from these studies had been determined to be comparable to each other since fish from the 1972/1973 survey had been kept frozen and analyzed using the same methodology as used for the 1980 survey (Singleton, 1983). Such verification was not possible for the data reported here since specimens collected in 1980 had been mishandled and were not available for analyses. A small number of samples from our 1988 survey have been sent to Environmental Protection of Environment Canada for future comparison testing.

In the following sections comparisons of levels found in both livers and muscles will be made to unpublished data on fish collected by the Ministry of Environment (MOE) at a number of lakes in British Columbia. Although it is recognized that levels would vary among species, the comparison is provided so that the reader can appreciate what natural ranges may be present at uncontaminated areas. Species of fish for which there were greater than 10 analyses were rainbow trout (115 analyses each for liver and muscle), cutthroat trout (76 liver analyses and 54 muscle analyses), Dolly Varden char (50 liver analyses and 51 muscle analyses), and mountain and lake whitefish (hereafter referred to simply as whitefish: 34 liver analyses and 35 muscle analyses). In presenting these data, we recognize that there will be considerable differences among species; however we feel that some idea of concentrations in fish from other areas is required in order to put data for Fraser River fish into some perspective.

3.1.1 ARSENIC

Quality control/assurance data for arsenic in muscle tissues are plotted in Figures 7(a) and 8(a) while data for livers are in Figures 9(e). The data in Figure 7(a) indicate that in terms of accuracy, arsenic values in tissues were within the certified range for seven of eight measurements, with the eighth value being about 1.5 µg/g low. In terms of analytical precision for duplicate analyses (Figure 8a), arsenic values were generally within 20% or less of each other, unless values were very close to the detection limit. For liver samples, one of two measurements was within the certified range, while the second was 0.005 µg/g less.

Thus, these data indicate that results reported here for arsenic may be skewed slightly low in comparison to certified ranges, and this may be more pronounced for liver data than for muscle tissue.

(a) Arsenic in Muscle Tissue

Arsenic was detected in all the fish muscle samples from all three sites. Singleton (1983) did report detectable arsenic concentrations; however, detection limits in the 1988 survey (0.025 µg/g dry-weight or 0.005 µg/g wet-weight) were significantly lower than used in the 1980 survey (2.0 µg/g dry-weight or 0.4 µg/g wet-weight). Arsenic concentrations in our survey, equal to or greater than the 1980 detection limits, were encountered in only one starry flounder sample from each of the North and Main Arm sites.

The highest mean arsenic concentrations were found in staghorn sculpins and starry flounders from the North and Main Arms. A comparison of the staghorn sculpin values using the F-test and student's t-test procedures (P=0.05) indicated no significant difference between sites for the mean values. For the starry flounders, the results of the F-test indicated statistically significant variability in the data between the two sites.

Significant variability between each of staghorn sculpin and starry flounders, and peamouth chub, largescale sucker and northern squawfish data (F-test:P=0.05) was noted for samples from both the North Arm and the Main Arm sites, as well as between staghorn sculpin and starry flounders at the North Arm site. In the Main Arm, the variability of the staghorn sculpin and starry flounder data was statistically similar (F-test: P=0.05), although the mean values of 0.15 and 0.25 µg/g were not (Student's t-test: P=0.05).

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.033	0.016	0.023	0.003
Cutthroat Trout	0.025	0.019	0.022	0.002
Dolly Varden	0.158	0.019	0.034	0.029
Whitefish	0.040	0.015	0.024	0.005

Generally speaking, mean arsenic concentrations in Fraser River fish muscle are two or more times greater than in fish from uncontaminated lakes. These data cannot be tested statistically due to significant variability between the data sets.

(b) Arsenic in Livers

Adequate numbers of liver samples to permit comparions of concentrations were available for largescale suckers, northern squawfish, and peamouth chub from each of the North and Main Arms and for staghorn sculpins from the Main Arm (Table 3).

Within species, mean concentrations between the Main Arm and North Arm were statistically similar (F-test; Student's t-test: P=0.05) for peamouth chub (0.21 and 0.25 µg/g, respectively), northern squawfish (0.17 and 0.256 µg/g, respectively), and largescale sucker (0.129 and 0.051 µg/g, respectively).

For fish from along each each of the North and Main Arms, all mean arsenic concentrations in livers from largescale suckers, northern squawfish, and peamouth chub from the same sites were statistically the same (F-test; Student's t-test: P=0.05), as were staghorn sculpins from the Main Arm to each of the other three species.

Singleton (1983) did not report detectable arsenic concentrations in livers from any of these four species. As reported in Singleton (1983) and also in this survey, higher arsenic values were found in liver than in muscle samples.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.059	0.017	0.023	0.006
Cutthroat Trout	0.132	0.016	0.028	0.020
Dolly Varden	0.045	0.017	0.024	0.005
Whitefish	0.046	0.016	0.024	0.007

Generally speaking, mean arsenic concentrations in Fraser River fish livers are two or more times greater than in fish from uncontaminated lakes. These data could not be tested statistically due to the generally high significant variability (F-test: P=0.05) between the data sets.

3.1.2 CADMIUM

Quality control/assurance data for cadmium in muscle tissues are plotted in Figures 7(a) and (e), while data for livers are in Figure 9 (f).

The data in Figure 7 indicate that all eight measured values were within certified ranges for the certified muscle tissue. In terms of precision, values were within 15% of each other once values exceeded about 1.7 µg/g; however, the deviation was as high as about 40% at lower concentrations. This trend in precision was also noted in the data used for determining accuracy.

For measurements in livers, one value (Figure 9) was at the lower end of the range while the second was slightly lower (≈0.002 µg/g dry). Thus the cadmium data for this survey, appear to be representative of true levels.

(a) Cadmium in Muscle Tissue

Cadmium was generally not detected (0.025 µg/g dry-weight, 0.005 µg/g wet-weight) in muscle tissue, although measurable values were found in one largescale sucker from the Main Stem, two of seven staghorn sculpin samples and five of eight starry flounder samples from the Main Arm. In total, cadmium was measurable in only eight of 127 samples.

Singleton (1983) detected (1.0 µg/g dry-weight, 0.2 µg/g wet-weight) cadmium in only 1 of 273 muscle tissue samples collected in 1980 along the entire length of the river. The higher detection limits in 1980 do not allow a meaningful comparison of these data to the 1988 results.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.325	0.178	0.228	0.029
Cutthroat Trout	0.247	0.186	0.217	0.017
Dolly Varden	0.263	0.189	0.220	0.019
Whitefish	0.309	0.148	0.224	0.038

Generally speaking, mean cadmium concentrations in Fraser River fish had considerably lower mean concentrations than fish from uncontaminated lakes.

(b) Cadmium in Livers

Adequate numbers of samples were obtained for only largescale suckers and peamouth chub from the North and Main Arms and for staghorn sculpins from the Main Arm (Table 3). Concentrations found in most northern squawfish from the Main and North Arms were generally not detectable (<0.005 µg/g). No statistically significant difference in mean concentrations were found between the Main Arm or North Arm for largescale suckers (0.092 and 0.06 µg/g, respectively) or peamouth chub (0.073 and 0.060 µg/g, respectively).

In the North Arm, the mean concentrations in largescale suckers and peamouth chub (0.06 µg/g, each) were statistically similar to each other as the levels in these fish and in staghorn sculpins were in the Main Arm (0.092, 0.073, and 0.147 µg/g, respectively).

Singleton (1983) reported that 32 of 43 liver samples (74.4% along the length of the Fraser River had detectable (>0.2 µg/g) cadmium concentrations. With this same detection limit in 1988, only 2 of 46 samples (4.3%) would have had detectable concentrations. As reported by Singleton (1983), cadmium concentrations in livers in the 1988 survey appear higher than in muscle tissue.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.657	0.173	0.230	0.052
Cutthroat Trout	0.478	0.163	0.218	0.042
Dolly Varden	0.418	0.169	0.247	0.055
Whitefish	0.666	0.164	0.242	0.087

Generally speaking, mean cadmium concentrations in Fraser River fish were less than in fish from uncontaminated lakes, although staghorn sculpin values were very close.

3.1.3 CHROMIUM

ASL Laboratories in performing the sample analyses, indicated that chromium, iron, molybdenum and nickel, metals normally associated with stainless steel, were elevated in starry founders and redside shiners. It was felt that contamination of these samples may have occurred in the laboratory due to problems encountered in homogenizing these whole fish. Apparently, fish bones would seize the tissue homogenizer leaving the samples warm or hot and not entirely homogeneous.

Quality control/assurance data for chromium in muscle tissues are plotted in Figures 7(f) and 8(b). The data in Figure 7 indicate that five of eight chromium values were within certified ranges for muscle tissue. There did not appear to be a bias to the data being either higher or lower than certified. Precision data (Figure 8) for chromium indicated that for values greater than about 1.0 µg/g dry, duplicate measurements were within about 20% of each other. There was no certified range for chromium in livers.

These data indicate that chromium values would be highly variable, with no particular bias to the data which would usually be accurate.

(a) Chromium in Muscle Tissue

Data collected in 1980 were based on a detection limit of 1.0 µg/g dry-weighted (0.2 µg/g wet-weight; Singleton 1983). Six of 26 detectable values at that time (of 273 samples) were from fish from the North Arm, with the remaining 20 fish with detectable levels coming from the upper reaches of the Fraser River.

The detection limit during the 1988 survey was reduced to 0.05 µg/g dry-weight (0.01 µg/g wet-weight). The highest mean values in 1988 were in starry flounders from the North Arm, however this may reflect contamination from within the laboratory (see Section 3.1.3). Therefore, results for these fish and the redside shiner will be excluded from further discussion.

Within each fish species, the highest mean chromium concentrations were in fish from the North Arm. Using the F-test and Student's t-test to compare these mean values to those found in the Main Arm and Main Stem for the same fish species, statistically significant variability existed for largescale sucker and northern squawfish between the North Arm and Main Arm sites, and for peamouth chub between the North Arm and Main Stem sites. This means that the ranges of values do not overlap adequately to allow us to assume that the data for each are from the same population. Mean values were significantly different (Student's t-test: P=0.05) for largescale suckers from the North Arm and Main Stem sites and peamouth chub between the North Arm and Main Arm sites. Only mean chromium values for northern squawfish of 0.03 µg/g in the Main Stem and 0.08 µg/g in the North Arm were statistically similar.

Within sampling sites, the variability of chromium in northern squawfish in the Main Arm in comparison to largescale sucker, peamouth chub and staghorn sculpin was significant (F-test: P=0.05). Mean chromium values of 0.06 µg/g for largescale sucker, 0.04 µg/g for peamouth chub, and 0.06 µg/g for staghorn sculpin did not vary significantly (Student's t-test: P=0.05) in the Main Arm.

Between species from the North Arm, significant variability between data sets occurred between staghorn sculpin and largescale sucker, as well as these species and peamouth chub and northern squawfish (F-test: P=0.05). The mean chromium values of 0.08 µg/g for northern squawfish and 0.16 µg/g for peamouth chub were significantly different (Student's t-test: P=0.05).

In the Main Stem, significant variability existed between the northern squawfish and peamouth chub data (F-test:P=0.05), but not largescale sucker and peamouth chub. The mean values of 0.05 µg/g for largescale sucker and 0.03 µg/g for northern squawfish were statistically similar (Student's t-test: P=0.05); however, such was not the case for largescale sucker and the mean chromium value of 0.02 µg/g for peamouth chub.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.876	0.178	0.267	0.110
Cutthroat Trout	0.738	0.186	0.249	0.120
Dolly Varden	0.585	0.191	0.231	0.058
Whitefish	0.309	0.148	0.224	0.038

Some Fraser River fish species had mean chromium concentrations which were considerably less than fish from uncontaminated lakes, while others were considerably higher.

(b) Chromium in Liver Tissues

Adequate numbers of samples on which to make comparisons were available for largescale sucker, northern squawfish, and peamouth chub from the Main and North Arms and staghorn sculpin from the Main Arm. The variability of the data for peamouth chub and largescale sucker was significant for these species between the two Arms (F-test: P=0.05). For northern squawfish, the mean value of 0.046 μg/g in the North Arm was statistically similar to 0.078 μg/g found in the Main Arm (F-test; Student's t-test: P=0.05).

In the North Arm, the data for peamouth chub varied significantly to those for either largescale sucker or northern squawfish (F-test: P=0.05). The mean values of 0.085 μg/g for largescale sucker was statistically similar to 0.046 μg/g for northern squawfish (F-test; Student's t-test: P=0.05). In the Main Arm, the mean values of 0.148, 0.078, 0.065, and 0.20 μg/g for largescale sucker, northern squawfish, peamouth chub, and staghorn sculpin, respectively were statistically the same (F-test; Student's t-test: P=0.05), thereby indicating a wide range of values at these levels.

Singleton (1983) suggested that the livers may not be an active site for the accumulation of chromium in fish. A species by species, and site by site, comparison of mean concentrations in muscle tissue and livers from this study tends to support Singleton's conclusion.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	1.69	0.173	0.347	0.26
Cutthroat Trout	0.99	0.169	0.297	0.16
Dolly Varden	0.86	0.169	0.283	0.14
Whitefish	2.42	0.164	0.331	0.43

Generally speaking, chromium concentrations in Fraser River fish livers were considerably less than in fish from uncontaminated lakes.

3.1.4 COPPER

Quality control/assurance data for copper in muscle tissues are plotted in Figures 7(d) and (g) and 8(c), while data for livers are in Figure 9(b).

The data in Figure 7 indicate that copper values were measured within the certified range of values at low levels (<6 µg/g-dry) for three of four measurements (the fourth value being 0.01 µg/g outside the range), but all four measurements were lower than the certified range at values in excess of 400 µg/g dry. Values measured in the 1988 survey would generally be associated with the former range of certified values. In terms of duplicate analyses indicating precision, values greater than about 1.7 µg/g were within about 15% of each other (Figure 8). Both copper measurements in liver were within the certified range.

Thus copper values found in the 1988 survey can be considered accurate.

(a) Copper in Muscle Tissue

Copper concentrations were measured in largescale suckers, peamouth chub, and northern squawfish in surveys conducted in 1972/1973 and 1980 (reported in Singleton, 1983), as well as in this survey. A comparison of the range and mean values is shown in Figure 2. Generally, the range and mean values for 1980 and this survey appear similar, while the range of values in 1972/1973 was wider. Singleton (1983) reported "that copper in fish downstream from Hope was significantly lower in many cases, during the 1980 survey".

Within each fish species, the highest mean values were in the Main Stem for largescale sucker; in the North Arm for peamouth chub, staghorn sculpin, and starry flounder; and in the Main Arm for squawfish. Variability was found to be significant between starry founders, staghorn sculpins, and peamouth chub, from the North and Main Arms (F-test: P=0.05), while variability was similar for other species between sites.

The mean value of 0.20 µg/g for largescale sucker from the North Arm was significantly lower than mean values for the same species of 0.27 µg/g in the Main Arm or 0.33 µg/g in the Main Stem (F-test; Student's t-test: P=0.05), while the latter two values were statistically similar to each other. Similarly, the mean value of 0.24 µg/g in northern squawfish from the North Arm was significantly lower than the mean value of 0.32 µg/g in the Main Stem or 0.34 µg/g in the Main Arm (F-test; Student's t-test: P=0.05), while the latter two values were statistically similar. The mean value of 0.29 µg/g in peamouth chub from the Main Stem was statistically similar to the mean value of 0.39 µg/g for the North Arm.

Within sampling sites, mean copper concentrations in largescale sucker, northern squawfish, and peamouth chub from the Main Stem were statistically similar to each other (F-test; Student's t-test: P=0.05). The variability of the data for redside shiner from the Main Stem was significantly different from that of northern squawfish (F-test: P=0.05), while the mean value of 1.04 µg/g for redside shiner was significantly higher than those means for largescale sucker (0.33 µg/g) or peamouth chub (0.29 µg/g) (Student's t-test: P=0.05).

Significant variability in data in the North Arm occurred between each of staghorn sculpin, starry flounder and largescale sucker, as well as between each of these and each of northern squawfish and peamouth chub (F-test: P=0.05). The mean values of 0.39 µg/g copper in peamouth chub from the North Arm was significantly higher than the mean of 0.24 µg/g in northern squawfish (F-test; Student's t-test: P=0.05).

Significant variability existed in data for starry flounders from the Main Arm in comparison to data from the same site for staghorn sculpins, peamouth chub, northern squawfish or largescale sucker (F-test: P=0.05). The variability of data for these latter four species in comparison to each other was similar. In the Main Arm, the mean value of 0.27 µg/g for largescale sucker was significantly lower than the mean value of 0.35 µg/g for staghorn sculpin or 0.37 µg/g for peamouth chub (F-test; Student's t-test: P=0.05), but not in comparison to 0.34 μg/g for northern squawfish. Other mean values were statistically similar to each other.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	1.96	0.183	0.385	0.292
Cutthroat Trout	0.884	0.186	0.297	0.137
Dolly Varden	1.03	0.189	0.378	0.198
Whitefish	1.01	0.148	0.301	0.172

Generally speaking, the mean concentrations in Fraser River fish were quite similar to mean copper concentrations in fish from uncontaminated lakes, although some Fraser River fish species were higher.

(b) Copper in Livers

Adequate numbers of liver samples were obtained for largescale suckers, northern squawfish, and peamouth chub from the North and Main Arms and of staghorn sculpin in the Main Arm to make some comparisons. The mean concentration for peamouth chub of 3.06 μg/g in livers from the North Arm was statistically similar to 3.08 μg/g from the Main Arm, the mean concentration for largescale sucker of 3.75 μg/g for the North Arm was significantly lower than 6.73 μg/g for the Main Arm, and for northern squawfish, the mean concentration of 3.45 μg/g in the Main Arm was significantly lower than 5.08 μg/g in the North Arm (F-test; Student's t-test: P=0.05).

In the North Arm, the mean concentration of 5.08 μg/g in northern squawfish was significantly higher than the statistically similar values of 3.75 μg/g in largescale sucker and 3.06 μg/g in peamouth chub (F-test; Student's t-test: P=0.05). In the Main Arm, the variability of the northern squawfish data was significantly different from largescale sucker and staghorn sculpin (F-test: P=0.05). The mean concentration of 3.45 µg/g for northern squawfish was statistically similar to 3.08 µg/g for peamouth chub, but both were significantly lower than 6.73 µg/g for largescale sucker and 9.77 µg/g for staghorn sculpin (F-test; Student's t-test: P=0.05).

Mean copper concentrations in livers, when compared species to species and site to site to concentrations in muscle tissue, were considerably higher. This agrees with the findings of Singleton (1983).

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	261	0.669	51.2	46.9
Cutthroat Trout	164	2.29	19.4	26.7
Dolly Varden	114	1.32	14.4	18.8
Whitefish	39.4	1.12	3.78	6.57

Fraser River fish had considerably lower mean copper concentrations in livers than fish from uncontaminated lakes.

3.1.5 IRON

Starry flounder and redside shiner are suspected of being contaminated with iron (see Section 3.1.3). Therefore no further discussion will be made for these two species.

Quality control/assurance data for iron in muscle tissues are plotted in Figures 7(b) and (c) and 8(d), while data for livers are in Figure 9(b). The data in Figure 7 indicate that two of four measurements were within the certified range with a third being 0.5 µg/g higher than the range and the fourth 2.5 µg/g lower than the range when values were in the order of 65 µg/g. When higher iron values (≈185 µg/g) were present in the certified sample, three of four measurements were below the certified range. In the

1988 survey, iron values for largescale suckers, northern squawfish, and peamouth chub were even lower than the lower certified range, and therefore were likely accurate. However, iron values in some other species (e.g. staghorn sculpin) were sometimes as high as the higher certified range, and therefore may have actually been low in comparison to the "true" values.

When duplicate analyses were performed, values were within about 13% of each other when values were above 30 µg/g (dry-weight). This is also reflected in the accuracy data in Figure 7. In terms of livers, one of two values was within the certified range which was about 195 µg/g, while the second was only slightly (8 µg/g) lower.

Thus iron values reported for 1988 are likely accurate.

(a) Iron in Muscle Tissue

Singleton (1983) reported that iron concentrations did not vary significantly between the three river reaches, or vary in comparison to results from the 1972/1973 survey. Results are presented in Figure 3 for peamouth chub, northern squawfish, and largescale sucker from the three surveys. From Figure 3, it seems likely that Singleton's conclusions can be extended to include the 1988 data set.

Within fish species, the highest mean iron concentration (12 µg/g) was in staghorn sculpin from the North Arm. However, the variability of the data at this site was significantly different from each of the other species (F-test: P=0.05), therefore this mean value will not be considered further. The variability of the data for largescale sucker, northern squawfish, and peamouth chub between each site was similar. The mean value of 3.81 µg/g for largescale sucker from the Main Arm was significantly lower than the mean values of 6.84 µg/g in the North Arm or 7.09 µg/g in the Main Stem (F-test; Student's t-test: P=0.05), while the latter two values were not significantly different from each other. The mean values of 4.34 µg/g for northern squawfish and 5.02 µg/g for peamouth chub in the North Arm were statistically similar to the mean values of 3.87 μg/g and 5.07 μg/g, respectively in the Main Arm and 5.15 μg/g and 3.96 μg/g, respectively in the Main Stem; however, there was a significant difference noted between the Main Stem and Main Arm values for both species.

Within sampling sites, the variability of the data was statistically similar (F-test: P=0.05) between each of staghorn sculpin (excluding the North Arm site), peamouth chub, northern squawfish, and largescale sucker. The mean iron value of 5.15 μg/g in northern squawfish from the Main Stem was statistically similar to the mean value for largescale sucker of 7.09 μg/g and peamouth chub of 3.96 μg/g from the same site, although the latter two values were significantly different from each other (Student's t-test: P=0.05).

The mean iron value of 4.34 μg/g in northern squawfish from the North Arm was statistically similar to the mean value of 5.02 μg/g in peamouth chub; however, at the same site both were significantly lower than the mean concentration of 7.09 μg/g in largescale sucker. In the Main Arm, there was no significant difference between the mean iron values of 3.81 μg/g in largescale sucker, 3.87 μg/g in northern squawfish or 5.07 μg/g in peamouth chub (Student's t-test: P=0.05). There was also no difference between the mean value of 5.53 μg/g in staghorn sculpin and 5.07 μg/g in peamouth chub, even though the mean value in staghorn sculpin was significantly higher than the mean value found in largescale sucker or northern squawfish.

(b) Iron in Livers

Adequate numbers of liver samples were analyzed for comparisons to be made for only largescale sucker, northern squawfish, and peamouth chub in the Main and North Arms and for staghorn sculpin the Main Arm. Within each of the three species found in the two Arms, no statistically significant difference was found (F-test; Student's t-test: P=0.05).

In the North Arm, there was no statistically significant difference between mean concentrations of 111 µg/g in largescale sucker, 117 µg/g in northern squawfish, or 96.1 µg/g in peamouth chub (F-test; Student's t-test: P=0.05).

In the Main Arm, the variability of the liver data for largescale suckers was significantly different from peamouth chub (F-test: P=0.05); however, its mean concentration of 119 µg/g was statistically similar to 118 µg/g in northern squawfish, and 109 µg/g in staghorn sculpin (F-test; Student's t-test: P=0.05). These latter two values were also similar to that of 97.7 µg/g in peamouth chub.

Singleton (1983) reported detectable iron concentrations in all samples, and that the lowest concentration of 51.1 µg/g was found in sockeye salmon from the North Arm. In this survey, the lowest concentration of 49.4 µg/g was found in peamouth chub from the North Arm (no salmon were tested in 1988). Mean iron concentrations in livers, when compared to the same species from the same site, were higher than in the muscle tissue.

3.1.6 LEAD

Quality control/assurance data for lead in muscle tissue are in Figures 7(a) and (f) and 8(e), while data for livers are in Figure 9(f). The data in Figure 7 indicate that all eight measurements were within certified ranges. All measured lead values in muscle tissues (Table 2) were approximately the same as the lower certified range.

Duplicate analyses were usually within 20% of each other although there were some differences as high as 45%. However, at the low values measured (<0.25 µg/g dry-weight), this would amount to a difference of 0.11 µg/g dry-weight or about 0.02 µg/g on a wet-weight basis. For livers (Figure 9), one of two measurements was within the certified range while the second was only slightly higher (0.02 µg/g dry-weight).

Thus it can generally be said that the lead data for 1988 were accurate and reflect true levels in both muscle and liver tissues.

(a) Lead in Muscle Tissue

Singleton (1983) reported that only 18 of 273 muscle tissues collected in 1980 had detectable (1.0 µg/g dry-weight or 0.2 µg/g wet-weight) lead concentrations, with 14 of the 18 values being in fish downstream from Hope. Singleton (1983) reported that using the same detection limits, only 4 of 554 fish taken downstream from Hope in 1972/1973 had measurable lead concentrations. As well, in 1980, staghorn sculpins "exhibited the highest percentage of samples with detectable lead levels" (Singleton 1988).

The analytical detection limit used for the 1988 data was twenty times lower than that used in the previous two surveys. Had the same detection limits been used in this survey, we would be reporting that lead was not detected in any of the 127 samples analyzed. Even with the significantly lower detection limits, 18 of the 127 samples had non-detectable lead values (8 of 12 largescale suckers, 7 of 10 northern squawfish, and 3 of 7 peamouth chub). All lead concentrations in all species were below the 0.8 µg/g alert level established by the MOE for edible portions of fish (Nagpal 1987). Of interest, all the non-detectable concentrations were in fish from the Main Arm, while the highest mean values by species (Table 2) was in fish from the North Arm. The North Arm receives significant flows of stormwater with associated high lead values (Swain and Holms, 1985).

The variability of lead concentrations within different species was significant between sampling sites (F-test: P=0.05) for northern squawfish, peamouth chub, and starry flounder. This is surprising since it would have been suspected that fish from the Main Arm and Main Stem would be similar. The variability of the data was not significant for largescale sucker in the North Arm and Main Stem (data for Main Arm were too low to permit the application of statistical tests), or staghorn sculpin in the Main and North Arms.

In the Main Stem, lead data were more highly variable for peamouth chub in comparison to largescale sucker, northern squawfish, or redside shiners (F-test: P=0.05). For these remaining three species, redside shiner data were more highly variable than northern squawfish data. The mean lead value of 0.02 µg/g in largescale suckers was statistically similar to the mean value of 0.03 µg/g in both northern squawfish and redside shiner (F-test; Student's t-test: P=0.05).

In the North Arm, lead data were more highly variable for both peamouth chub and starry flounder in comparison to those for each of largescale sucker, northern squawfish, and staghorn sculpin. In comparison to each other, peamouth chub and starry flounder had similar variability in data as did largescale sucker, peamouth chub, and staghorn sculpin. The mean lead values of 0.03 µg/g for largescale sucker and northern squawfish were not significantly different from the value of 0.04 µg/g for staghorn sculpin (F-test; Student's t-test: P=0.05). Similarly the mean value of 0.05 µg/g for peamouth chub was not statistically different from the value of 0.07 µg/g for starry flounder.

The low concentration of lead in muscle tissue from the Main Arm resulted in statistical testing techniques being applied to data for only three species; peamouth chub, staghorn sculpin, and starry flounders. The variability of the data sets for these three species was similar to each other (F-test: P=0.05); however none of the mean values were statistically similar to each other (Student's t-test: P=0.05). This latter fact is of particular interest for the case of staghorn sculpin and starry flounder, each with a mean value of 0.02 µg/g. The statistical testing was performed on dry-weight concentrations and "rounding-off" to wet-weight equivalents led to two identical wet-weights not being statistically similar.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.896	0.159	0.284	0.134
Cutthroat Trout	1.93	0.169	0.358	0.260
Dolly Varden	0.651	0.189	0.262	0.117
Whitefish	1.60	0.148	0.312	0.279

Generally speaking, mean lead concentrations in Fraser River fish muscle were at least four times lower than in fish from uncontaminated lakes.

(b) Lead in Livers

Adequate numbers of liver samples for comparison purposes were found for largescale suckers in the North and Main Arms, northern squawfish and peamouth chub in the North Arm, and staghorn sculpin in the Main Arm. The variability of the data for largescale suckers was significant and the data from the North and Main Arms could not be compared (F-test: P=0.05).

In the North Arm, the mean concentration in liver of 0.044 µg/g in peamouth chub was significantly lower than 0.086 µg/g in northern squawfish, but the former was not statistically different from 0.068 µg/g in largescale suckers (F-test; Student's t-test: P=0.05), while the northern squawfish value was also similar to that of the largescale sucker.

Singleton (1983) reported that only 3 of 43 samples in the 1980 survey were above the detection limit of 0.2 µg/g. In this survey, all lead concentrations were less than or equal to 0.2 µg/g.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	16.9	0.188	0.462	1.72
Cutthroat Trout	1.93	0.169	0.358	0.26
Dolly Varden	1.06	0.169	0.305	0.186
Whitefish	1.18	0.164	0.370	0.308

Generally speaking, mean lead concentrations in livers from Fraser River fish were about four times lower than found in fish from uncontaminated lakes.

3.1.7 MANGANESE

Quality control/assurance data for manganese in muscle tissue are in Figures 7(a) and (g) and 8(g) while data for livers are in Figure 9(g). The data in Figure 7 indicate that five of eight manganese measurements were within the certified ranges, with three measured values being below the certified range when in the order of 25 μg/g dry-weight. Values in the 1988 survey (Table 2) for most species were close to the lower certified range of values (<2 μg/g); however, data for redside shiner, starry flounder, and threespine stickleback were usually as high or higher than the former range of certified values.

For duplicate analyses, low values (<2 μg/g) were found to have differences as high as 30%, but this difference was reduced to about 10% when values were >5 μg/g (Figure 3). Measurements of livers were both in the certified range (Figure 9).

Thus the manganese data for the 1988 survey can be considered to be accurate, and reflect true conditions.

(a) Manganese in Muscle Tissue

Manganese data for largescale suckers, northern squawfish, and peamouth chub are plotted in Figure 4 for this survey and those in 1980 and 1972/1973. Singleton (1983) reported that in comparison to the 1980 data, "the average manganese concentrations were significantly higher at several sites downstream from Hope during the 1972/1973 study". An examination of Figure 4 indicates that for some species at some sites (e.g. all three species in the Main Arm), 1988 mean values are similar to those from 1980; however some species at some sites (e.g., northern squawfish and largescale sucker from the Main Stem) have mean values for 1988 approaching those found in the 1972/1973 survey.

Singleton (1983) found that within species, there was no significant difference among the various sites during 1980. For 1988, similar variability of data within species but between sites existed for largescale sucker, peamouth chub, and northern squawfish from the North and Main Arms. Significant variability existed for starry flounder and staghorn sculpin between sites, and for northern squawfish from the Main Stem and each of the other two sites (F-test: P=0.05). The mean manganese value of 0.27 µg/g in largescale suckers from the Main Arm was statistically lower than the value of 0.39 µg/g in the Main Stem, with both these values being statistically similar to the mean of 0.32 µg/g in the North Arm. Mean manganese values of 0.24 µg/g, 0.28 µg/g, and 0.20 µg/g for peamouth chub from the Main Stem, North Arm, and Main Arm, respectively, were statistically similar (Student's t-test: P=0.05). Mean manganese values for northern squawfish of 0.17 µg/g for the Main Arm and 0.19 µg/g for the North Arm were statistically similar (Student's t-test: P=0.05).

In the Main Stem, the variability of the data was statistically different between redside shiners and northern squawfish, and each of these with peamouth chub and largescale sucker (F-test: P=0.05). The variability of the data for largescale sucker and peamouth chub was similar; however, their mean manganese values of 0.39 µg/g and 0.24 µg/g, were statistically different (Student's t-test: P=0.05).

In the North Arm, the variability of the data was significant for starry flounder and staghorn sculpin in comparison to each other, as well as each of these with largescale sucker, northern squawfish and peamouth chub (F-test: P=0.05). The variability of the data for these latter three species in comparison to each other was statistically similar, as were the mean values of 0.32 µg/g for largescale sucker and 0.28 µg/g for peamouth chub (Student's t-test: P=0.05). The mean value of 0.19 µg/g for northern squawfish was significantly lower than the mean manganese value for largescale sucker or peamouth chub.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	1.13	0.178	0.265	0.130
Cutthroat Trout	1.20	0.186	0.289	0.171
Dolly Varden	1.50	0.189	0.324	0.238
Whitefish	0.693	0.148	0.294	0.146

Mean copper concentrations in largescale suckers, northern squawfish, peamouth chub, and staghorn sculpin were of similar magnitude to fish from uncontaminated lakes, while those for redside shiner, starry flounder, and threespine stickleback were considerably higher.

(b) Manganese in Livers

Adequate numbers of liver samples were available for largescale suckers, northern squawfish, and peamouth chub in the Main and North Arms and staghorn sculpins in the Main Arm to make comparisons.

The data for largescale suckers and peamouth chub each varied significantly between the North and Main Arms (F-test: P=0.05). For northern squawfish, the mean concentration of 0.69 µg/g in the North Arm was statistically similar to 0.83 µg/g in the Main Arm.

In the North Arm, the variability of both the largescale sucker and peamouth chub data was significantly different from that of northern squawfish (F-test: P=0.05). The mean concentration of 1.54 µg/g for largescale sucker was statistically similar to 2.11 µg/g in peamouth chub (F-test; Student's t-test: P=0.05).

In the Main Arm, the variability of the data for largescale sucker was statistically different from that of each of northern squawfish, peamouth chub, and staghorn sculpin (F-test: P=0.05). The mean concentration of

1.24 µg/g for staghorn sculpins was significantly higher than the mean concentration of 0.81 µg/g for peamouth chub, but not statistically higher than the mean concentration of 0.83 µg/g for northern squawfish (F-test; Student's t-test: P=0.05).

Singleton (1983) reported that manganese values in livers were generally 5 to 10 times greater than found in muscle tissue. This was also generally true in this survey. As well, in common with the 1980 survey, in this survey it was found that the highest concentration in livers occurred in largescale suckers from the Main Arm.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	12.4	0.223	1.57	1.19
Cutthroat Trout	2.62	0.360	1.37	0.357
Dolly Varden	4.28	0.338	1.55	0.791
Whitefish	3.33	0.82	1.76	0.531

Mean manganese concentrations in livers from Fraser River fish were approximately the same as for fish from uncontaminated lakes, except for livers from largescale suckers from the Main Arm which were considerably higher.

3.1.8 MERCURY

Quality control/assurance data for mercury in muscle tissue are in Figures 7(f) and 8(h), while data for livers are in Figure 9(d). All eight measurements were within the two certified ranges of values.

Duplicate analyses were within about 15% of each other when values exceeded 0.4 µg/g dry-weight and were generally less than 20% of each other when values were less than 0.4 µg/g dry-weight (Figure 8). For liver samples, both mercury measurements were below the certified range, and below detection.

These data indicate that although mercury data in fish muscle tissues were accurate, data for livers were lower than the true values.

(a) Mercury in Muscle Tissue

Singleton (1983) reported finding the highest mercury concentration in 1980 in a northern squawfish captured near Chilliwack. Mercury data for the 1972/1973, 1980, and 1988 surveys for largescale sucker, northern squawfish, and peamouth chub are plotted in Figure 5. Interestingly, at each site for each of the three surveys, the highest mercury value was found in northern squawfish. As well, for all three species from all three sites, the mean concentration and the maximum value has been steadily reduced in magnitude from 1972 to 1988.

Singleton (1983) supported the argument put forth by Northcote et. al. (1975) that mercury concentrations in fish muscle tissue are related to the trophic level of the fish in the food web, and since northern squawfish are of higher trophic status, these could have higher mercury concentrations.

All mercury concentrations for all species were at or below the proposed MOE criterion of a maximum of 0.5 µg/g wet weight, although this criterion is reduced for people whose diet is based primarily on fish (MOE draft report).

Within species, variability of the data was not significant between the different sites for starry flounder, staghorn sculpin, peamouth chub, or largescale sucker between the North and Main Arm sites, and peamouth chub in the North Arm and those at each of the Main Stem and Main Arm sites (F-test: P=0.05). Significant variability in mercury data occurred for largescale suckers between the Main Stem and each of the North and Main Arms, and northern squawfish between the Main Stem and Main Arm.

The mean values of 0.04 µg/g and 0.05 µg/g for starry flounder, 0.07 µg/g and 0.10 µg/g for staghorn sculpins, and 0.24 µg/g and 0.23 µg/g for peamouth chub, from the Main and North Arms respectively, were statistically similar to each other (Student's t-test: P=0.05). Similarly, the mean values for northern squawfish of 0.39 µg/g at the North Arm and 0.35 µg/g at the Main Stem were not significantly different. Significantly lower mean values were found for largescale suckers between the North (0.08 µg/g) and Main Arms (0.10 µg/g), as well as for northern squawfish between these same two sites (0.39 µg/g and 0.27 µg/g, respectively) (Student's t-test: P=0.05).

In the Main Stem, the variability of the redside shiner mercury data was similar to that of peamouth chub (F-test: P=0.05), as was that of peamouth chub to northern squawfish and largescale sucker. Redside shiner had significant variability in data compared to that of northern squawfish and largescale sucker, while peamouth chub data were different to northern squawfish. The mean value of 0.11 µg/g for largescale sucker was statistically similar to that of 0.12 µg/g for peamouth chub (Student's t-test: P=0.05) but significantly lower than the value of 0.35 µg/g for northern squawfish. The mean value of 0.12 µg/g for peamouth chub was significantly higher than the mean value of 0.06 µg/g for redside shiner (Student's t-test: P=0.05).

In the North Arm, the variability was similar between data for starry flounder and each of largescale sucker, northern squawfish, peamouth chub, and staghorn sculpin; between staghorn sculpin and each of peamouth chub and largescale sucker; and between peamouth chub and largescale sucker (F-test: P=0.05). Significant variability between data bases existed for northern squawfish and largescale sucker, peamouth chub, and staghorn sculpin. All of the remaining mean values of 0.08 µg/g for largescale sucker, 0.39 µg/g for northern squawfish, 0.23 µg/g for peamouth chub, 0.10 µg/g for staghorn sculpin, or 0.05 µg/g for starry flounder were statistically different (Student's t-test: P=0.05).

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.30	0.10	0.09	0.05
Cutthroat Trout	1.30	0.10	0.30	0.25
Dolly Varden	1.50	0.10	0.15	0.22
Whitefish	0.40	0.10	0.13	0.09

Mean mercury concentrations in Fraser River fish muscle were generally of the same order of magnitude as in fish from uncontaminated lakes.

(b) Mercury in Livers

Adequate numbers of liver samples were available for largescale suckers, northern squawfish, and peamouth chub in the North and Main Arms and in staghorn sculpins in the Main Arm on which to make meaningful comparisons. The variability of the data for peamouth chub was statistically different between the North and Main Arms (F-test: P=0.05). The mean mercury concentrations in livers of largescale suckers and northern squawfish, when compared for the same species between sites, were not significantly different from each other (F-test; Student's t-test: P=0.05).

In the North Arm, the mean concentration of 0.028 µg/g in largescale suckers was significantly lower than the value of 0.118 µg/g in northern squawfish, but was statistically the same as the concentration of 0.10 µg/g in peamouth chub (F-test; Student's t-test: P=0.05). These latter two concentrations were statistically similar to each other.

In the Main Arm, the mean concentration of 0.14 µg/g in staghorn sculpin was significantly higher than the values 0.03 µg/g in largescale suckers, 0.068 µg/g in northern squawfish, and 0.09 µg/g in peamouth chub (F-test; Student's t-test: P=0.05). Each of these latter three values were also significantly different from each other.

The mean mercury concentration in livers was lower for largescale suckers, northern squawfish and peamouth chub than mean concentrations in muscle tissues, while those in staghorn sculpins were higher. This, in general, agrees with findings for the 1980 survey reported by Singleton (1983). Inasmuch as these findings differ, as noted by Singleton (1983), from the findings of two other researchers (Peterson et al. (1970), Reid and Morley (1975)) who worked with fish from Pinchi Lake, a lake into which tailings from a mercury mine had been dumped, it can be inferred that significant mercury contamination is not occurring in the lower Fraser River and estuary. Singleton (1983) stated, "in Fraser River fish, elimination exceeded uptake of mercury whereas in Pinchi Lake fish, uptake exceeded elimination".

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	0.4	0.1	0.11	0.10
Cutthroat Trout	0.9	0.1	0.35	0.25
Dolly Varden	0.4	0.1	0.11	0.12
Whitefish	0.4	0.1	0.19	0.09

Mean concentrations in livers from Fraser River fish were of the same magnitude as mercury in livers of fish from uncontaminated lakes.

3.1.9 MOLYBDENUM

Quality control/assurance data for molybdenum in muscle tissue are in Figure 7(g), while data for livers are in Figure 9(g). A certified range of values was only available for lobster, and all four molybdenum measurements were within the certified range. Molybdenum was usually not detected in duplicate (<0.25 μg/g dry-weight) analyses. In liver analyses, one of two measurements were within the certified range of values, while the second was slightly (≈0.3 μg/g) lower.

Thus, molybdenum values in both muscle and liver tissues are likely accurate.

(a) Molybdenum in Muscle Tissue

Molybdenum was generally not detected (<0.05 µg/g wet-weight) except in redside shiner and threespine stickleback (whole fish) and starry flounder and staghorn sculpin. The maximum concentration of 0.23 µg/g was found in threespine stickleback from the North Arm of the Fraser River (Table 2).

Singleton (1983) reported that eight fish from the estuary area had detectable molybdenum concentrations, but that Northcote et al. had found no fish with detectable (<0.2 µg/g) concentrations in 1972/1973.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	1.20	0.178	0.268	0.138
Cutthroat Trout	0.247	0.186	0.217	0.017
Dolly Varden	0.436	0.189	0.229	0.045
Whitefish	0.496	0.148	0.231	0.059

Generally, all mean concentrations in muscle tissue from Fraser River fish were considerably lower than mean values for fish from uncontaminated lakes, although threespine stickleback were similar.

(b) Molybdenum in Liver Tissue

The highest molybdenum concentration (0.22 µg/g) was found in livers from starry flounder from the North Arm and largescale suckers from the Main Stem and Main Arm. Comparisons within species could only be made for largescale suckers and peamouth chub from the North and Main Arms. The mean values for largescale suckers of 0.16 µg/g in the North Arm and 0.19 µg/g in the Main Arm, and for peamouth chub of 0.154 µg/g in the North Arm and 0.138 µg/g in the Main Arm were not significantly different from each other (F-test; Student's t-test: P=0.05).

Within the North Arm, the mean values of 0.16 µg/g for largescale suckers was not significantly different from the value of 0.154 µg/g for peamouth chub (F-test; Student's t-test: P=0.05). In the Main Arm, the mean concentration of 0.138 µg/g in peamouth chub was significantly lower than the mean value of 0.19 µg/g for largescale suckers and significantly higher than the mean values of 0.087 µg/g for staghorn sculpin and 0.093 µg/g for northern squawfish.

Molybdenum concentrations in livers were generally higher (i.e., detectable) than found in muscle tissue.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	1.65	0.173	0.333	0.261
Cutthroat Trout	1.46	0.163	0.34	0.214
Dolly Varden	0.47	0.169	0.257	0.069
Whitefish	0.446	0.164	0.249	0.063

Mean concentrations in livers from Fraser River fish were about one-half those in fish from uncontaminated lakes.

3.1.10 NICKEL

In Section 3.1.3, it was noted that the analytical laboratory suspected elevated nickel levels in starry flounders and redside shiners, possibly due to problems in homogenizing the samples in the laboratory. Therefore, results for these species will not be discussed further.

Quality control/assurance data for nickel in muscle tissue are in Figure 7(g) and 8(i). A certified range of values was not available for livers. All eight nickel measurements in muscle were within the certified range of values for both lobster and dogfish. Actual measurements of duplicate samples indicated a difference of about 15% above 0.25 µg/g (dry-weight).

These data indicate that nickel measurements for muscle tissue were accurate and fairly precise.

(a) Nickel in Muscle Tissue

Nickel was not detected (<0.2 µg/g) in any of the fish collected in the estuary area by Singleton (1983) in 1980 or by Northcote et al. (1975) in 1972/1973. Detectable concentrations were found in this survey since the detection limit was reduced to 0.01 µg/g.

Within species, variability between river reaches was significantly different for peamouth chub from the North Arm in comparison to each of the Main Stem and Main Arm and for staghorn sculpin between the North Arm and Main Arm (F-test: P=0.05).

In the Main Stem and the Main Arm, the mean concentrations in largescale suckers, northern squawfish, and peamouth chub (0.06 and 0.05 µg/g, respectively, for each species) were statistically similar to each other (F-test; Student's t-test: P=0.05), while in the North Arm, the concentrations of nickel in peamouth chub (0.26 µg/g) and staghorn sculpin (0.49 µg/g) were significantly higher than in each of northern squawfish (0.04 µg/g) and largescale suckers (0.04 µg/g). The mean nickel concentration in staghorn sculpin (0.08 µg/g) from the Main Arm was statistically similar to that found in largescale suckers, northern squawfish, and peamouth chub.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	1.63	0.89	1.14	0.146
Cutthroat Trout	1.55	0.95	1.11	0.108
Dolly Varden	1.32	0.96	1.11	0.093
Whitefish	1.55	0.79	1.13	0.188

The mean concentrations in Fraser River fish were generally considerably lower than in fish from uncontaminated lakes, except for starry flounder and threespine stickleback which, from the North Arm, were about twice as high.

(b) Nickel in Livers

Adequate numbers of liver samples to permit comparisons of concentrations were found in largescale suckers, northern squawfish, and peamouth chub from the North and Main Arms and in staghorn sculpins from the Main Arm (Table 3).

Within species, significant variability existed for northern squawfish and peamouth chub between the Main and North Arms (F-test: P=0.05). The mean concentrations in largescale suckers of 0.145 µg/g from the North Arm and 0.183 µg/g from the Main Arm were statistically similar (F-test; Student's t-test: P=0.05).

In fish collected from the North Arm, significant variability existed between peamouth chub and northern squawfish (F-test: P=0.05). The mean concentration of 0.076 µg/g in northern squawfish was significantly lower than 0.145 µg/g in largescale sucker; however, the mean concentration of 0.145 µg/g in largescale sucker was statistically similar to 0.123 µg/g found in peamouth chub (F-test; Student's t-test: P=0.05).

In fish collected from the Main Arm, significant variability existed between largescale sucker data and northern squawfish (F-test: P=0.05). The mean concentrations of 0.06 μg/g in northern squawfish and 0.043 μg/g in peamouth chub were statistically similar to each other (F-test; Student's t-test: P=0.05), while the concentration in peamouth chub was significantly lower than the 0.183 μg/g measured in the largescale sucker.

Mean nickel concentrations seemed to be higher in livers of largescale suckers than in muscle tissue, but about the same in northern squawfish and peamouth chub.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	2.36	0.865	1.15	0.218
Cutthroat Trout	4.59	0.845	1.15	0.536
Dolly Varden	1.84	0.845	1.20	0.223
Whitefish	1.78	0.910	1.17	0.179

Generally, mean concentrations in muscle tissue from Fraser River fish were considerably lower than from fish from uncontaminated lakes except for threespine stickleback and starry flounder from the North Arm which were about twice as high.

3.1.11 ZINC

Quality control/assurance data for zinc in muscle tissues are plotted in Figures 7(a) and (c) and 8(j), while data for livers are in Figure 9(a).

The data in Figure 7 indicate that 5 of 8 measurements of muscle tissue were within the certified ranges of values, while the other three measurements were slightly lower. Duplicate analyses of muscle tissue samples (Figure 8(j) were generally within 20% of each other below 30 μg/g dry-weight or less than 5% at concentrations greater than 100 μg/g.

For livers, 1 of 2 measurements was within the certified range of values, while the second measurement was only 1 μg/g below the range.

It is likely that most zinc values are accurate, or only slightly below true values.

(a) Zinc in Muscle Tissue

Zinc concentrations in muscle tissue for largescale sucker, northern squawfish and peamouth chub are plotted in Figure 6 for the three surveys. Mean values in the Main Stem (except for peamouth chub which may be skewed) for the three species do not appear to have changed to any great degree, although maximum values have been reduced since the 1972/1973 survey. In the Main Arm, mean values seem to be slightly reduced for northern squawfish and largescale sucker, but reduced considerably for peamouth chub, while values in the North Arm appear to be about the same.

Within species, there was no significant variability in zinc data between any of the sites for largescale sucker or northern squawfish, but significant variability for starry flounder and staghorn sculpin data (F-test: P=0.05). For peamouth chub, there was significant variability between data for the Main Stem and North Arm, but not between the North and Main Arms. There was no significant difference in mean values as follows: for largescale sucker, 5.27 μg/g in the Main Stem, 5.36 μg/g in the North Arm, or 4.71 μg/g in the Main Arm; for northern squawfish, 4.47 μg/g in the Main Stem, 5.00 μg/g in the North Arm or 4.44 μg/g in the Main Arm; and for peamouth chub, 5.89 μg/g in the North Arm and 5.69 μg/g in the Main Arm (Student's t-test: P=0.05).

In the Main Stem, the variability of zinc data for redside shiner was significant in comparison to each of largescale sucker, peamouth chub, and northern squawfish, although these latter three species in comparison to each other had similar variability (F-test: P=0.05). The mean value of 5.27 μg/g for largescale sucker was statistically similar to 4.47 μg/g in northern squawfish and 5.28 µg/g for peamouth chub, but the mean concentration for northern squawfish was significantly lower than for peamouth chub in comparison to each other (Student's t-test: P=0.05).

In the North Arm, there was significant variability in zinc concentrations between all species of fish except between peamouth chub and largescale sucker (F-test: P=0.05). The mean values of 5.89 ug/g and 5.36 µg/g were statistically similar (Student's t-test: P=0.05).

In the Main Arm, the variability of zinc data for all species in comparison to each other was similar except for starry flounder which was more highly variable than for the other species (F-test: P=0.05). The mean value of 4.44 µg/g for northern squawfish was statistically similar to that of 4.71 µg/g for largescale sucker and both were similar to the mean value of 5.07 µg/g for staghorn sculpin (Student's t-test: P=0.05). However, both were significantly lower than 5.69 µg/g for peamouth chub (Student's t-test: P=0.05).

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	10.71	2.29	4.29	1.35
Cutthroat Trout	5.24	2.21	3.55	0.64
Dolly Varden	7.30	2.91	3.78	0.79
Whitefish	36.77	2.57	5.40	5.67

Generally, zinc concentrations in muscle tissue from Fraser River fish were about the same as in fish from uncontaminated lakes. Exceptions to this were redside shiner, starry flounder, and threespine stickleback which were about five times higher.

(b) Zinc in Livers

Adequate numbers of liver samples were collected from largescale suckers, northern squawfish, and peamouth chub in the North and Main Arms, and staghorn sculpins in the Main Arm to permit comparisons. The mean concentrations of these former three species when compared to each other for the Main and North Arm sites were statistically similar (F-test; Student's t-test: P=0.05).

In the North Arm, the variability of the data for largescale suckers was significantly different to that for peamouth chub (F-test: P=0.05). The mean concentration of 15.5 µg/g for northern squawfish was significantly higher than the concentration of 13.7 µg/g for peamouth chub and significantly lower than the concentration of 22.5 µg/g for largescale suckers (F-test; Student's t-test: P=0.05).

In the Main Arm, the variability of the data for staghorn sculpins was significantly different to that of the other three species. The mean zinc concentration of 13.3 µg/g for peamouth chub was statistically similar to 15.5 µg/g for northern squawfish; however, both were significantly lower than the mean concentration of 25.6 µg/g for largescale suckers (F-test; Student's t-test: P=0.05).

Singleton (1983) reported that in the 1980 survey, "average zinc concentrations in livers were normally about five to ten times greater than the average muscle tissue concentrations". Similar results were found for the 1988 survey.

The MOE data were as follows:

Species	Maximum	Minimum	Mean	Standard Deviation
Rainbow Trout	179.6	6.47	28.75	16.8
Cutthroat Trout	40.7	0.181	23.72	5.99
Dolly Varden	50.0	14.5	30.2	7.19
Whitefish	41.2	16.6	23.8	4.54

Generally, mean concentrations in livers from Fraser River fish were similar to those in fish from uncontaminated lakes, except for staghorn sculpin which were about twice as high.

3.1.12 CONCLUSIONS

Analytical detection limits used in the 1988 survey were considerably lower than used in the 1980 or 1972/1973 surveys. Although fish from 1972/1973 had been retained and measured prior to the 1980 survey to confirm that the results from the 1972/1973 could be compared to 1980, fish kept from 1980 were lost in subsequent years so that comparisons could not be made between the 1980 survey and this one. Thus comparisons of the 1988 data to those from previous surveys must be made with caution, and the quality control data from this survey become highly important.

In terms of accuracy of results for both liver and muscle tissues, it is important to note that most measurements made by the laboratory on certified specimens were either within the certified range of values or only slightly lower than the range. Exceptions to this were for mercury in livers, which was reported as not detectable (detection limit is well below the certified range of values), and one lead measurement in liver which was slightly higher than the certified range. Duplicate analyses of the split samples were generally within 20% of each other.

Other quality control measurements were made with regard to possible contamination of the samples during the digestion process. Usually, metals could not be detected, although at least once, some slight contamination was noted with chromium, copper, iron, lead, nickel and zinc in muscle tissues, and iron and nickel in livers. Contaminant levels were so low on these occasions that it was not deemed necessary to make corrections to the data on this basis.

Due to the fact that starry flounders and redside shiners were not filleted, considerable problems were encountered in preparation of the samples. The laboratory suspects that for these two species, contamination occurred for chromium, iron, molybdenum, and nickel. Therefore, these metals were not discussed with respect to these two species.

Metal concentrations in fish tissue can vary significantly within the same species captured at different sites or among different species from the same sites. In this survey, similar variability of data as examined by the F-test, and statistically similar mean values, as examined by the Student's t-test, were found to be present more in the data on livers than on muscle tissue.

When variability within species between at least any two sampling sites was considered for muscle tissue, significantly different variability existed for peamouth chub for seven metals, for staghorn sculpin for six, and for largescale suckers, starry flounder and northern squawfish for four metals each. In livers, significantly different variability within species existed for four metals in peamouth chub, two metals for largescale suckers, and one metal for northern squawfish. The fact that variability existed between sites tells us that either a contaminant source is affecting the values in fish from a particular site, which was not readily apparent, or that the fish analyzed for those metals were not representative of the entire statistical population.

When comparing mean values in muscle tissues within species between at least any two sampling sites, statistically different values occurred for four metals in largescale suckers, two metals for peamouth chub, and three metals for northern squawfish. Copper in largescale suckers and northern squawfish was lower in the North Arm than the other two sites, and this was the only apparent trend from these data. In livers, different values were found only for copper in largescale suckers and northern squawfish.

As would be expected, there was considerably more variation in data and significantly different mean values when the different species at the same sites were compared to each other. This was evident for both muscle and liver tissues, and verifies that the different species had different amounts of metals.

Higher concentrations of metals were generally found in liver than in muscle, as was the case for the 1980 survey. Exceptions to this, which was also found in the 1980 survey, were for chromium and mercury. In the case of mercury, higher levels had been reported in liver than muscle tissue for fish from Pinchi Lake where mercury tailings had been deposited. This leads us to conclude that there does not appear to be a major source of mercury to the lower Fraser River.

In comparing metal levels in muscle tissues for five metals which can be compared among the 1972/1973, 1980 and this survey, values generally are similar or declining for copper, mercury, and zinc. Trends do not appear for iron or manganese.

In comparing mean metal concentrations found in Fraser River fish with those found in fish (different species) from uncontaminated lakes in British Columbia, it can generally be stated that concentrations were lower or of approximately the same magnitude. There were some exceptions to this general statement for a few species for some metals, and for all species for arsenic. However, it does not appear that present metal levels in Fraser River fish are different from what generally would be expected in other less industrialized areas.

3.2 CHLOROPHENOLS AND PCBs

Quality assurance of chlorophenols involved checking for contamination following digestion with six samples, following extraction using five liver and ten muscle samples, and checking the percent recovery of five spiked liver samples and ten spiked muscle samples. Contamination was not found to be present in any of the extraction samples (i.e. all values not detectable).

Percent recoveries of spiked samples for muscle tissue at concentrations ten times the detection limits ranged from 65% to 100% for trichlorophenol (mean 81%), from 72% to 100% for tetrachlorophenol (mean 81%), and from 47% to 90% for pentachlorophenol (mean 78%). The spiked samples consist of the organic in question being put into a solvent, and indicate possible losses in the analytical process past the point of extraction. Due to the artificial nature of this quality control process, losses which exist for the spike do not necessarily occur in the analysis of actual samples. Therefore, the percent recoveries likely indicate a "worst-case" situation. Since the results in Tables 4 and 5 have had no correction made for the recovery data, we will take these recovery data into account only when examining whether water quality objectives are achieved.

Percent recovery data for liver samples were as follows: from 66% to 78% (mean 75%) for trichlorophenol, from 65% to 83% (mean 76%) for tetrachlorophenol, and from 66% to 90% (mean 76%) for pentachlorophenol.

B.C. Ministry of Environment water quality objectives for chlorophenols in fish tissue are that there should be a maximum of 0.1 µg/g (wet-weight) in fish muscle (Swain and Holms, 1985). This objective relates to the sum of tri-, tetra-, and pentachlorophenol. This objective is achieved for all fish muscle tissue analyzed in this survey, even with corrections being made using the minimum percent recovery for each chlorophenol.

3.2.1 TRICHLOROPHENOL

(a) Trichlorophenol in Muscle Tissue

Trichlorophenols were not detected (<0.0002 µg/g) in largescale suckers from the Main Arm, peamouth chub and staghorn sculpins from the North and Main Arms, and threespine stickleback from the North Arm (Table 4). The variability of trichlorophenols measured in largescale suckers and northern squawfish, within each species, between the Main Stem and the North Arm, was significant (F-test: P=0.05).

Trichlorophenols were measured only in fish from the Main Stem and North Arm at a sufficient frequency so that a comparison of species at each site could be made. In the Main Stem, the data for redside shiner varied significantly from those for peamouth chub, northern squawfish, and largescale suckers (F-test: P=0.05). Therefore, the mean concentration for redside shiner will not be considered further. The mean concentration of 0.006 µg/g in peamouth chub was significantly higher than the value of 0.003 µg/g in northern squawfish or 0.002 µg/g in largescale suckers (Student's t-test: P=0.05).

At the North Arm site, the mean concentration of 0.007 µg/g in northern squawfish was significantly higher than 0.002 µg/g in largescale sucker but was not significantly different from 0.004 µg/g in starry flounder (F-test; Student's t-test: P=0.05).

Trichlorophenols in muscle tissue of five largescale suckers from the Main Arm (MA-2) in 1980 ranged from <0.02 to 0.08 µg/g (mean: 0.04 µg/g) (Singleton 1983). Trichlorophenols were not detected (<0.0002 µg/g) in muscle tissue from largescale suckers (n=11) in the 1988 survey. During the same 1980 survey, trichlorophenols were not detected (<0.02 µg/g) in muscle tissue from five largescale suckers collected from the upper North Arm.

Hall _et_ _al_. (1984) found the following concentrations of 2,4,6 - trichlorophenol in fish muscle tissue (or whole fish if very small) collected in November and December 1983:

Area	General Location	Species	Number	Concentration Wet-Weight (µg/g)
Main Arm	Ladner Harbour (East from MA-2)	Starry Flounder	3	0.52
Main Arm	Steveston Island (North from MA-2)	Starry Flounder	1	0.49
Main Arm	Annacis Island (Downstream end)	Peamouth Chub	36	1.44
North Arm	Near Mitchell Island	Starry Flounder	17	0.06
Middle Arm	SE corner of Sea Island	Starry Flounder	2	0.36

The validity of these data has been questioned (Personal Communication).

(b) Trichlorophenols in Livers

Trichlorophenols were generally not detected (<0.025 µg/g) in composite liver samples (Table 5), except in two of eight northern squawfish from the North Arm (0.047 and 0.094 µg/g). Due to the significantly higher detection limit for liver than for muscle (<0.0002 µg/g), it is not possible to determine if trichlorophenols are accumulating in liver. It is suspected that this may be occurring since the maximum concentration in fish muscle was only 0.017 µg/g which is considerably lower than the maximum values observed in livers.

3.2.2 TETRACHLOROPHENOL

Data for trichlorophenol are in Table 4 for muscle tissue and Table 5 for livers. Most values of tetrachlorophenol in muscle tissue were not detectable (<0.0002 µg/g).

During the 1980 survey, tetrachlorophenol was not detected (<0.01 µg/g) in muscle tissue from five largescale suckers from the upper North Arm (Singleton 1983). Detectable values were found in 4 of 5 muscle tissue samples from largescale suckers from the Main Arm (MA-2), where values ranged from <0.01 µg/g to 0.25 µg/g (mean: 0.10 µg/g).

Tetrachlorophenols were generally not detected (<0.025 µg/g) in composite liver samples. Exceptions to this were for one northern squawfish sample and two staghorn sculpins from the Main Arm, and one peamouth chub from the North Arm. It is suspected that tetrachlorophenol is accumulating in the livers of these species since the maximum values for muscle tissue for the same species were considerably lower than these measured values. However, the higher detection limit for livers compared to muscle tissue prevents a complete assessment of the data.

In 18 liver and muscle tissues of copper rockfish from Sechelt and Salmon Inlets collected between August and October 1987, all tetrachlorophenol results were <0.002 µg/g (Levings, 1989). The results were also obtained from ASL.

3.2.3 PENTACHLOROPHENOL

(a) Pentachlorophenol in Muscle Tissue

Pentachlorophenol was measured in muscle tissue of specimens from all species except threespine sticklebacks. Species by species, the variability of the data for northern squawfish from the North Arm was significantly different in comparison to those for either the Main Stem or Main Arm (F-test: $P=0.05$).

Generally, the mean concentrations in muscle tissue of all species was low, at 0.001 µg/g or 0.002 µg/g. The highest mean value for any species was 0.004 µg/g for redside shiners from the Main Stem, however these data varied significantly when compared to other species at this site (F-test: $P=0.05$).

Singleton (1983) reported that pentachlorophenol in muscle tissue of five largescale suckers collected in each of the Upper North Arm and the Main Arm (MA-2) ranged from 0.016 µg/g to 0.043 µg/g and from <0.01 µg/g to 0.19 µg/g, respectively. Mean values were 0.09 µg/g in the Main Arm and 0.03 µg/g in the North Arm. These values are considerably higher than measured in largescale suckers (North Arm; $n=17$: Main Arm; $n=11$) in this survey. This may be due to better management practices at locations using chlorophenols or a decrease in their use.

In 18 muscle tissues of copper rockfish from Sechelt and Salmon Inlets collected between August and October 1987, all pentachlorophenol values were <0.004 µg/g (Levings, 1989). ASL also performed these analyses.

(b) Pentachlorophenol in Livers

Pentachlorophenol was generally not detected (<0.025 µg/g) in composite liver samples. Exceptions to this were measured values in 1 of 9 peamouth chub from the North Arm, and 1 of 4 northern squawfish and 1 of 3 staghorn sculpins from the Main Arm. It appears that pentachlorophenol is accumulating in the livers of these species; however, a thorough examination of this is not possible due to the considerably higher detection limits for liver than for muscle (<0.0002 µg/g).

In 18 liver samples from copper rockfish collected between August and October 1987 in Sechlet and Salmon Inlets, pentachlorophenol values were <0.004 µg/g except for two values of 0.004 µg/g and one of 0.012 µg/g (Levings, 1989). ASL performed the laboratory analyses. Eleven analyses of livers from the same sources but analyzed by a second laboratory ranged from <0.78 to 17 ng/g.

3.2.4 POLYCHLORINATED BIPHENYLS (PCBs)

Quality assurance for PCBs involved checking for contamination following digestion with six samples, then following extraction using five samples, and finally checking the percent recovery of spiked samples. Contamination was not found to be present in any of the digestion or extraction samples (i.e. all values non-detectable).

Percent recoveries of spiked samples at concentrations ten times the detection limit ranged from 73% to 92% (mean 83%). The spiked samples do not necessarily indicate losses which would occur in the analyses (See Section 2.2.3). The results in Tables 4 and 5 have had no correction made for the recovery data.

(a) PCBs in Muscle Tissue

The B.C. Ministry of Environment has established a water quality objective of a maximum 0.5 µg/g (wet-weight) in muscle tissue (Swain and

Holms, 1985). Values in Table 4 indicate that the highest PCB concentration was about one-half the objective, or 0.26 µg/g. This was found in a largescale sucker from the North Arm. Interestingly, data for largescale suckers in the North Arm varied significantly in comparison to those from the Main Arm and Main Stem (F-test: P=0.05). Significant variability also existed for peamouth chub from the Main Stem in comparison to those from the North Arm.

Significant differences in mean concentrations by species occurred for northern squawfish in the North Arm where the 0.01 µg/g concentration was lower than in the Main Stem (0.04 µg/g) or Main Arm (0.03 µg/g) (F-test; Student's t-test: P=0.05).

Johnston _et_ _al_. (1975) reported on fish collected during 1972/1973. In the North Arm, no similar species were collected at NA-2 as in our survey; however, largescale suckers (n=4) and northern squawfish (n=2) had mean PCB concentrations of about 0.091 µg/g and 1.04 µg/g, respectively in muscle tissue from a site just downstream from New Westminster. These values are considerably higher than found in the North Arm in 1988, possibly due to improved effluent treatment at Paperboard Industries (formerly Belkin Packaging).

In the Main Arm, only northern squawfish (n=4) were captured at MA-2 in 1972/1973, with a mean concentration in muscle of about 0.123 µg/g (Johnston _et_ _al_. 1975). This mean is higher than recorded for any northern squawfish captured in 1988. In the Main Stem, one largescale sucker captured at MS-1 in 1972/1973 had a PCB concentration of 0.62 µg/g, considerably higher than found in the 1988 survey. PCB concentrations in single individuals of northern squawfish and peamouth chub in 1972/1973 were below detection (<0.002 µg/g) (Johnston _et_ _al_. 1975).

Singleton (1983) reported that measurable (>0.3 µg/g) PCB concentrations were found in 11 of 253 fish muscle tissue sampled in 1980. Nine of the 11 fish were from the North Arm, where detectable values ranged from 0.4 µg/g to 0.8 µg/g. All values for the 1988 survey were below the 0.3 µg/g detection limit.

Seventeen of 18 PCB values for copper rockfish collected between August and October 1987 in Sechelt and Salmon Inlets were <0.005 µg/g, with the eighteenth value being 0.007 µg/g (Levings, 1989). ASL performed the analyses.

(b) PCBs in Livers

The highest concentrations of PCBs in livers for all species (Table 5) except starry flounder were in fish from the North Arm. This is not surprising as Swain (1983) showed high concentrations of PCBs in the grit and sediment carried by stormwater into the North Arm where there is a very high concentration of stormwater outfalls. This, in conjunction with the relatively low flows in the North Arm in comparison to the other reaches, and the fact that one paper recycle operation in the past discharged PCBs to the North Arm (Swain 1980), explains why PCBs would be higher in fish from the North Arm.

Within species, this could only be tested statistically for largescale suckers and northern squawfish. The mean value of 0.222 µg/g in largescale suckers from the North Arm was significantly higher (F-test; Student's t-test: P=0.05) than the 0.105 µg/g found in largescale suckers from the Main Arm. There was not a statistical difference between the mean value of 0.252 µg/g in northern squawfish from the North Arm and the 0.19 µg/g in northern squawfish from the Main Stem, nor between those from the Main Stem and those from the Main Arm (0.083 µg/g). However, there was significant variability between the data for northern squawfish from the North and Main Arms.

In 18 liver samples from copper rockfish from Sechelt and Salmon Inlets, only one value was not detectable (<0.005 µg/g). The other values were as high as 0.31 µg/g, with a mean value of 0.088 µg/g (standard deviation 0.087) (Levings 1989). ASL performed the analyses. Eleven analyses of livers from the same survey performed by a second laboratory ranged from 0.05 to 0.6 µg/g (mean 0.245 µg/g).

3.2.5 CONCLUSIONS

The water quality objective for chlorophenols in muscle tissue in the Fraser River downstream from Kanaka Creek is a maximum of 0.1 µg/g (wet-weight), as the sum of tri-, tetra-, and pentachlorophenol. This objective was achieved for all fish muscle tissue analyzed in this survey.

Trichlorophenol concentrations in muscle tissue from peamouth chub from the Main Stem were significantly higher than those found in largescale suckers or northern squawfish from the same site. In the North Arm, the mean trichlorophenol concentration in muscle tissue from northern squawfish was significantly higher than found in largescale suckers from the same site.

In muscle tissue samples, tetrachlorophenols were not detected.

Pentachlorophenol concentrations in muscle tissue of all species were low, with mean values of 0.001 µg/g or 0.002 µg/g. Chlorophenol concentrations in muscle tissue appear to have been reduced considerably since the 1980 survey, possibly due to better management practices.

Chlorophenol concentrations in livers were difficult to compare to those in muscle tissue since the detection limit in liver was considerably higher. However, when maximum values in each were compared, it is speculated that all three chlorophenols measured may be accumlating in livers.

The water quality objective for PCBs in muscle tissue of a maximum of 0.5 µg/g (wet-weight) was achieved for all samples analysed in this survey. The mean PCB concentration in muscle tissue in northern squawfish from the

North Arm was significantly lower than found in the same species from the Main Stem or Main Arm.

PCB concentrations in muscle tissue appear to be lower than were recorded in 1972/1973 for the same species at the same sites. However, too few analyses were conducted in the earlier survey on which to make a meaningful comparison. Values for 1988 are also lower than measured in 1980.

The highest PCB levels by species except starry flounder were in fish from the North Arm. Of the two species with a sufficient data base, this was confirmed as well with statistical test for mean values in largescale suckers.

3.3 PHTHALATE ESTERS

Phthalic acid esters represent a large family of organic chemicals used widely as plasticizers (Leah 1977). Six phthalate esters were measured in this survey. These were dimethyl, diethyl, di-n-butyl, butyl benzyl, di-n-octyl, and bis (2-ethylhexyl). Quality assurance for phthalate esters in muscle involved checking for contamination following extraction with ten blank samples, as well as checking the percent recovery of ten spiked samples. In livers, five extraction blanks and five recovery spikes were analyzed.

Contamination was present for each of the six phthalate esters in at least one extraction blank. In the muscle tissues, the following was detected in the blanks:

Phthalate Ester	Number of Samples (of 10) with Detectable Concentrations	µg/g wet-weight Measured Concentrations	 Average Concentration For 10 samples
Dimethyl	2	0.088, 0.053	0.014
Diethyl	8	0.047, 0.088, 0.045 0.027, 0.034, 0.043, 0.026	0.082
Di-n-Butyl	9	0.026, 0.070, 0.046, 0.046, 0.029, 0.024, 0.098, 0.041, 0.032	0.042
Butyl Benzyl	5	0.038, 0.031, 0.046, 0.040 0.028	0.018
Di-n-octyl	2	0.11, 0.081	0.019
Bis (2-ethylhexyl)	3	0.072, 0.056, 0.094	0.022

These average concentrations should likely be considered as "background" concentrations due to the ubiquitous nature of phthalate esters.

Only when phthalate esters are present in fish muscle tissues at concentrations greater than the above "maximum" measured values will it be considered likely that the phthalates are present in the fish and not simply an artifact of laboratory analyses.

Contamination of livers was detected for only diethyl and bis (2-ethylhexyl) phthalate in the extraction blanks, as follows:

Phthalate Ester	Number of Samples (of 5) with Detectable Concentrations	µg/g wet-weight Measured Concentration(s)	 Average Concentration For 5 samples
Diethyl	3	0.28, 0.35, 0.26	0.18
Bis (2-ethylhexyl)	2	0.55, 0.61	0.23

Percent recoveries for spiked samples at concentrations ten times the detection limit were as follows:

Phthalate Ester	Muscle Tissue Percent Recovery Range	Mean	Livers Percent Recovery Range	Mean
Dimethyl	56-134	92.7	91-132	114.4
Diethyl	77-110	95.7	92-118	108.2
Di-n-Butyl	65- 88	77.3	81-118	96.6
Butyl Benzyl	58-104	84.3	92-126	111.
Di-n-octyl	62- 96	79.1	72-112	89.4
Bis (2-ethylhexyl)	66-102	86.8	84-114	96.
		Mean 86.0		Mean102.6

The spiked samples do not necessarily indicate losses which would occur in the analyses (see Section 2.2.3). The results in Tables 6 and 7 have had no correction made for the recovery data.

Metabolic degradation of phthalate acid esters is fairly rapid in fish and mammals (Inland Waters Directorate 1983). This would result in the highest concentrations being expected at the lower trophic levels.

3.3.1 DIMETHYL PHTHALATE

Data are summarized in Table 6 for muscle tissues and in Table 7 for livers.

(a) Dimethyl Phthalate in Muscle Tissue

Dimethyl phthalate was measured in some individuals of northern squawfish, peamouth chub, staghorn sculpins, and threespine sticklebacks from the North Arm (NA-2). Where measured, values were usually in excess of the "maximum background" for contamination, indicating that some dimethyl phthalate contamination of fish muscle is occurring.

Dimethyl phthalate was not detected (<10 µg/g) in muscle tissue from five largescale suckers from each of the Upper North Arm or the Main Arm (MA-2) in 1980 (Singleton 1983).

(b) Dimethyl Phthalate in Livers

Dimethyl phthalate was not detected (<0.5 µg/g) in any of the 46 composite liver samples analyzed. Since most values in muscle tissue were below detection (<0.01 µg/g), it was not possible to determine if dimethyl phthalate was accumulating in liver.

3.3.2 DIETHYL PHTHALATE

Data are summarized in Table 6 for muscle tissue and Table 7 for livers.

(a) Diethyl Phthalate in Muscle Tissue

Values in excess of 0.11 µg/g would be considered to be in excess of "maximum background" for contamination from laboratory sources. Most of the detectable concentrations exceeded this level, indicating that muscle tissue was being contaminated by diethyl phthalate. Several species had sufficient quantities of diethyl phthalate in their tissues so that average concentrations could be determined. These were usually from the North and Main Arms.

It was noted that significant variability existed in diethyl phthalate concentrations between the Main Arm and North Arm sites for largescale suckers, northern squawfish, and peamouth chub (F-test: P=0.05). The only other species collected at these two sites with calculated mean concentrations was staghorn sculpins with statistically similar mean values of 0.21 µg/g in the North Arm and 0.24 µg/g in the Main Arm(Student's t-test: P=0.05).

Fish tissue diethyl phthalate concentrations from the North Arm (NA-2) were comparable to each other as follows: peamouth chub had significant variability in comparison to staghorn sculpin (F-test: P=0.05) and had a mean value of 0.30 µg/g which was significantly higher than that (0.17 µg/g) for largescale suckers (F-test; Student's t-test: P=0.05). There was no significant difference between the mean concentration for northern squawfish (0.29 µg/g) and largescale suckers or northern squawfish and peamouth chub.

For fish from the Main Arm, significant variability existed between data for starry flounders and that of each of staghorn sculpins, northern squawfish, and largescale suckers (F-test: P=0.05) but not peamouth chub. The mean concentration of 0.60 µg/g for largescale suckers was significantly higher than mean values for northern squawfish or peamouth chub (0.23 µg/g), or staghorn sculpins (0.24 µg/g).

Diethyl phthalate was not detected (<10 µg/g) in any other tissues from five largescale suckers from each of the upper North Arm or Main Arm (MA-2) in 1980 (Singleton 1983).

(b) Diethyl Phthalate in Livers

Diethyl phthalates were detected (>0.2 µg/g) only in fish from the North Arm, with the highest concentration of 6.57 µg/g being measured in peamouth chub. The highest concentration found in extraction blanks was 0.35 µg/g. All detectable concentrations were considerably higher than this value. Thus, these high values are likely not artifacts of analyses.

3.3.3 DI-N-BUTYL PHTHALATE

Data are summarized in Table 6 for fish muscle and Table 7 for livers.

(a) Di-n-Butyl Phthalate in Muscle Tissue

Di-n-Butyl phthalate values in excess of 0.07 µg/g would be considered to exceed "maximum background" levels of contamination from laboratory and other sources which may be present in the samples. Some measurable minima and mean values were less than or equal to this level, indicating that di-n-butyl phthalate may not actually be present in those species. However, all maximum values were in excess of "maximum" background, indicating that some contamination of fish with di-n-butyl phthalate is occurring.

Within species variability between sites existed for largescale suckers from the Main Arm in comparison to each of the Main Stem and North Arm, northern squawfish from the North Arm in comparison to each of the Main Stem and Main Arm, and staghorn sculpins from the North Arm in comparison to the Main Arm (F-test: P=0.05). No statistically significant difference was present for the following mean concentrations: for largescale suckers, 0.07 µg/g in the Main Stem and 0.12 µg/g in the North Arm; for northern squawfish, 0.09 µg/g in the Main Stem and 0.06 µg/g in the Main Arm; for peamouth chub, 0.08 µg/g in the Main Arm and each of 0.06 µg/g in the North Arm or 0.15 µg/g in the Main Stem (although these latter two values were significantly different from each other); and for starry flounders, 0.07 µg/g in the North Arm and 0.06 µg/g in the Main Arm (F-test; Student's t-test: P=0.05).

For fish from the Main Stem, significant variability existed between data for redside shiner and each of northern squawfish and peamouth chub (F-test: P=0.05), although the mean concentration for redside shiner (0.09 µg/g) was not significantly different from that for largescale sucker (0.07 µg/g) (F-test; Student's t-test: P=0.05). There was also no statistically significant difference in the following mean values between species: 0.07 µg/g for largescale suckers, 0.09 µg/g for northern squawfish, and 0.15 µg/g for peamouth chub.

For fish from the North Arm, significant variability existed between data for northern squawfish and each of largescale suckers and staghorn sculpins, as well as between starry flounders and each of staghorn sculpins, peamouth chub, and largescale suckers (F-test: P=0.05). Mean concentrations of 0.08 µg/g for northern squawfish were not significantly different from 0.06 µg/g for peamouth chub or 0.07 µg/g for starry flounder (F-test; Student's t-test: P=0.05). The mean concentration of 0.06 µg/g for peamouth chub was similar to 0.08 µg/g for northern squawfish but was significantly lower than 0.12 µg/g in largescale suckers.

In the Main Arm, significant variability in data existed between largescale suckers and each of northern squawfish, peamouth chub, and staghorn sculpins and between staghorn sculpins and each of northern squawfish and peamouth chub (F-test: P=0.05). There was no significant difference between the following mean values: 0.06 µg/g for northern squawfish and starry flounder and 0.08 µg/g for peamouth chub (F-test; Student's t-test: P=0.05).

(b) Di-n-Butyl Phthalate in Livers

Di-n-butyl phthalate was detected (>0.2 µg/g) in livers from all species at all sites except peamouth chub from the Main Stem. The highest concentration of 9.39 µg/g was in livers from staghorn sculpins from the Main Arm. Values in livers were considerably higher than even the highest value found in muscle tissue, thus di-n-butyl phthalate seems to be accumulating in liver.

3.3.4 BUTYL BENZYL PHTHALATE

Data are summarized in Table 6 for muscle and Table 7 for liver.

(a) Butyl Benzyl Phthalate in Muscle Tissue

Values in excess of 0.046 µg/g would be considered to exceed "maximum background" levels of contamination from laboratory and other sources which may be present in the samples. Some measurable minimum, mean, and maximum values were less than this level, indicating that butyl benzyl phthalate may not be as widespread in muscle tissue as is implied by the data in Table 6.

Within species, significant variability between sites existed as follows: for largescale suckers between the Main Stem and the North Arm; for northern squawfish between the Main Stem and each of the North and Main Arms; and for staghorn sculpins between the North and Main Arms (F-test: P=0.05). The mean concentration of 0.07 µg/g for peamouth chub from the Main Stem was significantly higher than either the value of 0.02 µg/g measured in individuals from the North Arm or 0.04 µg/g in individuals from the Main Arm (F-test; Student's t-test: P=0.05). Otherwise, there was no significant difference in mean values between the North and Main Arms as follows: in largescale sucker with 0.02 µg/g at both sites; in northern squawfish with 0.04 µg/g at the North Arm and 0.03 µg/g at the Main Arm; in peamouth chub with 0.02 µg/g and 0.04 µg/g, respectively; and in starry flounders with 0.03 µg/g and 0.04 µg/g, respectively.

There was no significant difference between mean values of 0.06 µg/g for largescale sucker and northern squawfish and 0.07 µg/g for peamouth chub and redside shiner in the Main Stem (F-test; Student's t-test: P=0.05). In the North Arm, the mean value of 0.04 µg/g for northern squawfish was significantly higher than the 0.02 µg/g for largescale sucker or peamouth chub and 0.01 µg/g for staghorn sculpin, but similar to the 0.03 µg/g in starry flounder. This latter value was also significantly higher than the 0.01 µg/g in staghorn sculpin.

For fish collected from the Main Arm, significant variability existed between each of peamouth chub and staghorn sculpin, and largescale sucker and northern squawfish, as well as between starry flounder and largescale sucker (F-test: P=0.05). The mean concentrations of 0.03 µg/g for northern squawfish was similar to 0.02 µg/g for largescale suckers, while values of 0.04 µg/g were similar to each other for peamouth chub, staghorn sculpin, and starry flounders (F-test; Student's t-test: P=0.05). The value of 0.04 µg/g for starry flounders was significantly higher than 0.03 µg/g found in northern squawfish.

In 1980, muscle tissue from five largescale suckers from each of the upper North Arm and Main Arm (MA-2) had concentrations ranging from 0.029 µg/g to 0.042 µg/g and from 0.034 µg/g to 0.10 µg/g, respectively (Singleton 1988). Mean values were 0.037 µg/g in the North Arm and 0.053 µg/g in the Main Arm. In 1988, mean values were 0.02 µg/g in both Arms.

(b) Butyl Benzyl Phthalate in Livers

Butyl benzyl phthalate was detected (>0.2 µg/g) in most of the liver samples (Table 7). The highest concentration of 5.63 µg/g was in a largescale sucker from the Main Arm. Data at this site were more variable for largescale suckers and northern squawfish than for the same speces at the North Arm site.

Butyl benzyl phthalate, when maximum and mean values in livers are compared with those from muscle tissue, appears to be accumulating in livers.

3.3.5 DI-N-OCTYL PHTHALATE

Data are summarized in Table 6 for muscle tissue and Table 7 for livers.

(a) Di-n-Octyl Phthalate in Muscle Tissue

Values in excess of 0.11 µg/g would be considered to exceed "maximum background" levels of contamination from laboratory and other sources which may be present in the samples. One of two measurable minima (peamouth chub) was less than this level, and this value may be considered as actually being non-detectable. As well, the mean values for staghorn sculpins in the North Arm, and for peamouth chub and northern squawfish in the Main Stem were also less than this level.

Mean values were only calculated in the Main Stem for northern squawfish and peamouth chub and in the the North Arm in staghorn sculpin and threespine stickleback. The mean concentration of 0.08 µg/g in northern squawfish was not significantly different from the value of 0.04 µg/g in peamouth chub (F-test; Student's t-test: P=0.05).

Values of di-n-octyl phthalate in muscle tissue from fish from the estuary area are generally low. This is in contrast to what was reported by

Singleton (1983) for muscle tissue from five largescale suckers from each of the upper North Arm and the Main Arm (MA-2). Values ranged from 12 to 27 µg/g (mean - 16.8 µg/g) in the North Arm and from 9.2 to 15 µg/g (mean - 11 µg/g) in the Main Arm, considerably higher than measured in our survey.

(b) Di-n-Octyl Phthalate in Livers

Di-n-octyl phthalate was only detected (>0.5 µg/g) in northern squawfish from the North Arm. The high detection limit for livers in comparison to muscle tissue (<0.01 µg/g) and the large number of non-detectable liver results did not allow for an assessment of whether di-n-octyl phthalate was accumulating in liver.

3.3.6 BIS (2-ETHYLHEXYL) PHTHALATE

Data are summarized in Table 6 for muscle tissue and Table 7 for livers.

(a) Bis (2-Ethylhexyl) Phthalate in Muscle Tissue

Values in excess of 0.094 µg/g would be considered to exceed "maximum background" levels of contamination from laboratory and other sources which may be present in the samples. All measurable minima and some mean values were less than this level. This indicates that fish muscle may not be as highly contaminated with bis(2-ethylhexyl) phthalate as is implied by the data in Table 6.

Mean values were calculated for only two species at all sites sampled, northern squawfish and peamouth chub. The data for northern squawfish from the Main Stem varied significantly in comparison to those collected from the North or Main Arms (F-test: P=0.05). At these sites, there was no statistically significant difference between the mean values of 0.11 µg/g in the North Arm or 0.07 µg/g in the Main Arm (F-test; Student's t-test: P=0.05).

For peamouth chub, the mean concentration of 0.12 µg/g in fish from the Main Stem was significantly higher than the 0.05 µg/g in fish from the Main Arm, but not significantly higher than the 0.06 µg/g in fish from the North Arm (F-test; Student's t-test: P=0.05).

The only significant difference in mean values among species caught at the same site occurred in the North Arm, where the mean value of 0.11 µg/g in northern squawfish was significantly higher than the 0.06 µg/g in peamouth chub (F-test; Student's t-test: P=0.05).

(b) Bis (2-Ethylhexyl) Phthalate in Livers

Bis (2-Ethylhexyl) phthalate was detected at its highest concentration in peamouth chub (5.22 µg/g) from the Main Arm. Since the maximum concentration found in extraction blanks was 0.55 µg/g, it can be assumed relative to the detection level of 0.5 µg/g that any detectable bis (2-ethylhexyl) was likely real and not an artifact of analyses.

Maximum and where possible to calculate, mean concentrations in liver, were considerably higher than found in muscle tissue. This implies that bis (2-ethylhexyl) is accumulating in liver.

3.3.7 CONCLUSIONS

Laboratory sources of phthalates were considered to be responsible for individual phthalate concentrations up to a maximum of about 0.046 to 0.11 µg/g in fish muscle tissue. In liver, contamination did not seem to be as evident, likely due to the use of considerably higher detection limits. Nonetheless, contamination from laboratory sources of diethyl phthalate (0.35 µg/g) and bis (2-ethylhexyl) phthalate (0.61 µg/g) was measurable. In this study, values above these concentrations were considered to be indicative of possible real contamination while those below these levels were considered as being at non-detectable levels. The highest concentrations of phthalates would be expected in lower trophic levels.

Di-n-butyl phthalate and butyl benzyl phthalate were evident in the largest number of species and individuals of each species in muscle tissue. Conversely, dimethyl phthalate was detected in the fewest number of species and individuals.

Within species, levels of both butyl benzyl phthalate and bis (2-ethylhexyl) phthalate in fish from the Main Stem were found to be significantly higher than in fish from the Main and North Arms, and the Main Arm, respectively.

For muscle tissue, it appears that differences in data variability or mean values are random, and that no apparent trend exists for phthalate esters.

In liver, the following phthalate esters were found in some species at measureable levels: diethyl, di-n-butyl, butyl benzyl, and bis (2-ethylhexyl). This implies that some phthalate contamination of fish livers is taking place. Generally, there was an insufficient data base available to determine statistically if phthalates were accumulating in livers. However, it is suspected that di-n-butyl, butyl benzyl, and bis (2-ethylhexyl) phthalate may be accumulating.

3.4 POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

PAHs are commercially used compounds, are naturally present in coal and petroleum, and are also formed during the incomplete combustion of hydrocarbons (Garrett 1982). PAHs measured in this survey are acenaphthene, acenaphthylene, anthracene, benzo (a) anthracene, benzo (a) pyrene, benzo (b) fluoranthene, benzo (ghi) perylene, benzo (k) fluoranthene, chrysene, dibenzo (a h) anthracene, fluoranthene, fluorene, indeno (1,2,3-cd) pyrene, naphthalene, phenanthrene, and pyrene.

Quality assurance for PAHs involved checking for contamination following extraction with ten blank samples for muscle and five for liver tissue, as well as checking the percent recovery of the same numbers of spiked samples. PAHs were not detected in any of the extraction blanks.

Percent recoveries for ten spiked samples of muscle tissue and five for livers at concentrations ten times the detection limit were as follows:

	Muscle Tissue		Livers	
	Percent Range	Recovery Mean	Percent Range	Recovery Mean
Acenaphthene	52- 76	63.1	51-77	63.0
Acenaphthylene	50- 76	65.9	51-63	57.4
Anthracene	65-108	81.6	57-72	65.6
Benzo(a)anthracene	49-109	76.1	65-96	78.4
Benzo(a)pyrene	76-104	84.5	75-86	79.0
Benzo(b)fluoranthene	75-103	86.0	58-103	78.0
Benzo(ghi)perylene	58- 73	64.9	67-107	82.4
Benzo(k)fluoranthene	52-106	81.1	62-101	81.8
Chrysene	59- 91	78.2	62-109	87.2
Dibenzo(ah)anthracene	59-109	75.2	61-106	89.6
Fluoranthene	59-110	84.2	61- 98	79.6
Fluorene	41- 98	68.9	55- 78	64.6
Indeno (1,2,3-cd)pyrene	57- 68	61.6	66- 93	78.8
Naphthalene	45-107	67.1	42- 65	55.0
Phenanthrene	82-110	92.2	58- 93	70.2
Pyrene	65-104	91.9	65- 88	78.4
	Mean	76.4	Mean	74.3

The spiked samples do not necessarily indicate losses that would occur in the analyses (see Section 2.2.3). The results in Tables 8 and 9 have had no corrections made for the recovery data.

3.4.1 PAHS IN MUSCLE TISSUE

PAH data are summarized in Table 8 for muscle tissue. Detectable concentrations were found for the following PAHs: acenaphthene, fluoranthene, and phenanthrene in two threespine sticklebacks from the North

Arm; fluoranthene and phenanthrene in 2 of 3 starry flounders from the North Arm; and phenanthrene in 3 of 13 peamouth chub from the North Arm.

The North Arm of the Fraser River receives considerable stormwater runoff. PAHS are produced in the combustion of organic compounds and are also natural constituents of petroleum products, and therefore would be present on street surfaces. This is therefore the likely source, and the reason that some individual PAHs are detected in some fish from the North Arm.

3.4.2 PAHS IN LIVERS

PAH data for livers are summarized in Table 9. PAHs were detected in considerably more livers than muscle tissue. This is surprising since the detection limit for livers was five times higher than for muscle tissues. This indicates that PAHs are likely accumulating in livers. The most commonly detectable PAHs in livers were fluorene, naphthalene, and phenanthrene. Only for the data base for naphthalene were there sufficient detectable values to make a statistical comparison.

The mean naphthalene concentrations in fish (largescale sucker, peamouth chub, northern squawfish) from the North and Main Arms were not significantly different (F-test; Student's t-test: P=0.05).

At the North Arm site, the variability of the naphthalene data for largescale suckers was significantly different from northern squawfish data (F-test: P=0.05). The mean concentration of naphthalene in peamouth chub livers (0.064 µg/g) was not significantly different from largescale suckers (0.033 µg/g) or northern squawfish (0.079 µg/g) (F-test; Student's t-test: P=0.05).

At the Main Arm site, there was no significant difference in mean naphthalene concentrations for largescale suckers (0.051 µg/g), northern squawfish (0.064 µg/g), peamouth chub (0.059 µg/g), or staghorn sculpins (0.054 µg/g).

3.4.3 CONCLUSIONS

PAHs were measured in muscle tissue from fish only from the North Arm of the Fraser River, an area which would receive considerable stormwater runoff.

PAHs were found in considerably more liver samples than muscle tissues. This is surprising inasmuch as the detection limit for livers was five times higher than for muscle tissues. Therefore, PAHs are likely accumulating in livers.

Naphthalene was the only PAH found at a sufficient frequency in fish livers for which to make a statistical comparison. Generally, there was no significant difference within species or between the Main Arm and North Arm.

3.5 ORGANOCHLORINE PESTICIDES

Organochlorine pesticides tested for were aldrin, alpha-chlordane, gamma-chlordane, dieldrin, DDT, DDD, DDE, endrin, endosulfan I, endosulfan II, endosulfan sulfate, heptachlor, heptachlor epoxide, lindane, methoxychlor, and toxaphene. Results are summarized in Table 10 for muscle and Table 11 for liver.

Quality assurance for organochlorine pesticides involved checking for contamination following extraction with ten blank samples in muscle and five blank samples in livers, as well as checking the percent recovery of spiked samples (ten for muscle, five for liver). Organochlorine pesticides were not detected in any of the extraction blanks for either muscle or liver.

Percent recoveries for ten spiked muscle and five spiked liver samples at concentrations ten times the detection limit were as follows:

Organochlorine Pesticide	Muscle Tissue Percent Recovery		Livers Percent Recovery	
	Range	Mean	Range	Mean
Aldrin	57 - 96	75.0	66 - 82	72.6
alpha-chlordane	44 - 97	72.6	62 - 89	75.2
gamma-chlordane	67 - 94	77.2	82 -108	93.4
Dieldrin	69 - 94	77.0	65 - 82	74.0
DDT	57 -107	79.0	90 -125	102.0
DDD	58 -109	87.4	73 - 88	83.4
DDE	68 - 96	78.7	75 - 90	82.8
Endrin	65 - 95	77.2	72 -106	86.6
Endosulfan I	62 - 89	72.2	66 - 84	75.6
Endosulfan II	65 - 92	76.1	84 -114	96.2
Endosulfan Sulfate	43 - 89	69.8	77 - 96	84.6
Heptachlor	56 -103	74.3	81 -109	98.8
Heptachlor epoxide	64 - 94	76.5	66 - 74	69.0
Lindane	54 - 86	69.7	80 -101	88.0
Methoxychlor	45 -110	74.4	66 - 83	74.0
Toxaphene	no data	-	-	
	Mean	75.8	Mean	83.7

The spiked samples do not necessarily indicate losses that would occur in the analyses (see Section 2.2.3). The results in Tables 10 and 11 have had no corrections made for the recovery data.

3.5.1 ORGANOCHLORINE PESTICIDES IN MUSCLE TISSUE

The most commonly detected organochlorine pesticides were alpha- and gamma - chlordane, dieldrin, DDT, DDD, DDE, and methoxychlor. Occasionally, detectable values may have been encountered for some other pesticides.

The only organochlorine pesticide measured frequently in all species at most sites was DDE. Significant variability existed in data for northern squawfish between those captured in the Main Stem compared to those from each of the Main and North Arms and for peamouth chub between the Main Arm and Main Stem (F-test: P=0.05). The mean DDE concentration in northern squawfish from the North Arm (8.1 ng/g) was significantly higher than found in the Main Arm (3.74 ng/g) (F-test; Student's t-test: P=0.05). The mean values of 1.83 ng/g in the North Arm and 1.64 ng/g in the Main Arm in staghorn sculpins, and 1.35 ng/g in the North Arm and 1.89 ng/g in the Main Arm in starry flounders were not significantly different.

For fish from the Main Stem, significant variability existed between data sets for northern squawfish, peamouth chub, and redside shiner (F-test: P=0.05). Therefore the mean values for these species will not be considered further.

Data for DDE in northern squawfish from the North Arm were significantly more variable than those for staghorn sculpin or starry flounders (F-test: P=0.05). There was no significant difference in the mean concentrations of 1.83 ng/g for staghorn sculpin and 1.35 ng/g for starry flounder (F-test; Student's t-test: P=0.05).

For fish from the Main Arm, only data for staghorn sculpin varied significantly in comparison to the other four species (F-test: P=0.05). The mean value for largescale suckers of 1.51 ng/g was significantly lower than 3.74 ng/g in northern squawfish and 4.61 ng/g in peamouth chub (F-test; Student's t-test: P=0.05). These latter two mean concentrations were similar to each other and to the 1.89 ng/g measured in starry flounder.

Johnston et al. (1975) reported levels of organochlorine pesticides measured in muscle tissue of fish collected in 1972/1973. Aldrin, alpha- and gamma chlordane, heptachlor and lindane could not be detected (<2 ng/g) in any fish in the earlier survey. If the same detection limit was used in our survey, one staghorn sculpin from the North Arm would have had a measurable alpha-chlordane concentration (2.33 ng/g). Johnston et al. had explained the absence of aldrin and heptachlor by their quick chemical degradation to dieldrin and heptachlor epoxide, respectively, and the absence of lindane to a short half life in fish muscle (<2 days).

Johnston et al. (1975) reported that dieldrin, heptachlor epoxide, p,p^1-DDT, and p,p^1-DDD could not be detected (<2 ng/g) in northern squawfish (n=4) in the Main Arm at Site MA-2 (nor in 6 largescale suckers, 7 northern squawfish or 3 peamouth chub at other Main Arm sites). This was also the case in the Main Stem (Site MS-1) for single individuals of largescale sucker, northern squawfish, and peamouth chub. Similar fish species were not analyzed for the North Arm Site NA-2 as are reported for our survey; however, dieldrin and p,p^1-DDD were not detected (<2 ng/g) in four largescale suckers or two northern squawfish from an upstream North Arm site in the 1972/1973 survey (Johnston et al. 1975). One of the largescale suckers had p,p^1-DDT concentration of 12.9 ng/g and one northern squawfish a heptachlor epoxide value of 8.6 ng/g.

As for our survey, DDE (actually p,p^1-DDE in 1972/1973) was frequently measured in 1972/1973 (Johnston et al. 1975), as follows:

	p,p^1-DDE Concentrations (ng/g)					
Species	North Arm		Main Arm (MA-2)		Main Stem (MS-1)	
	n	Mean	n	Mean	n	Mean
Largescale Sucker	4	7.2	-	-	1	<2
Northern Squawfish	2	238.3	4	36.4	1	329.3
Peamouth Chub	-	-	-	-	1	<2

Values of DDE in 1988, especially for northern squawfish, appear to be considerably reduced from the 1972/1973 results. In general, values for organochlorine pesticides seem to be reduced from earlier levels.

Johnston et al. (1975) felt that the very low levels of organochlorine pesticides in 1972/1973 samples suggested that these compounds did not constitute a serious environmental problem.

3.5.2 ORGANOCHLORINE PESTICIDES IN LIVERS

The most commonly detected organochlorine pesticides in livers were alpha- and gamma- chlordane, dieldrin, DDT, DDD, DDE, endrin, and endosulfan I. The other organochlorine pesticides were not detectable (varying detection limits, see Table 11). Detection limits for liver were considerably higher than for muscle tissue.

Only DDD and DDE were measured frequently in livers in all species at most sites. The highest DDD value was 0.05 µg/g in a largescale sucker from the Main Arm. The highest DDE value of 0.16 µg/g was recorded in each of northern squawfish and peamouth chub from the North Arm.

The mean DDD concentrations in livers of largescale suckers of 0.019 µg/g in the North Arm and 0.028 µg/g in the Main Arm were not statistically different (F-test; Student's t-test: P=0.05). For this species at these two sites, the DDE data varied significantly. The mean DDE values for northern squawfish of 0.074 µg/g in the North Arm was not statistically different from 0.044 µg/g in the Main Arm (F-test: P=0.05).

Eleven analyses of livers were performed on copper rockfish from Sechelt and Salmon Inlets (Levings 1989). The results were as follows:

				(ng/g)	
		Maximum	Minimum	Mean	Std. Dev.
o, p^1	DDD	26	<0.22	3.8	7.6
p, p^1	DDD	130	1.8	26.4	37.3
p, p^1	DDT	270	8.4	50.4	75.1
o, p^1	DDT	44	1.9	11.4	12.3
o, p^1	DDE	<1.9	<0.23	-	-
p, p^1	DDE	240	8.2	63.6	48.3

3.5.3 CONCLUSIONS

The most commonly measured organochlorine pesticides in muscle and liver were alpha- and gamma- chlordane, dieldrin, DDT, DDD, and DDE. Of these, only DDE was measured frequently enough at all sites so that some comparisons could be made. Most mean values in muscle and liver for the same species we[illegible]t different between sites, except in muscle for northern squawfish from the North Arm which was significantly higher than those from the Main Arm.

For different species at the same site, the mean concentration of DDE in muscle of largescale suckers from the Main Arm was significantly lower than found in northern squawfish or peamouth chub.

Concentrations of organochlorine pesticides in muscle tissue appear to be reduced in comparison to values measured for fish captured in 1972/1973. These compounds were not considered to be a serious environmental problem at that time, and thus are likely even less so now.

3.6 GENERAL OBSERVATIONS

From the previous sections in Chapter 3, one gets the general impression that differences between species are random and that there does not seem to be any real patterns. As well, it was not obvious that fish collected from Barnston Island were any less contaminated than from the two downstream sites. However, this comparison was difficult due to the differences in species collected.

Data for metals for different fish species from uncontaminated lakes throught British Columbia were generally at higher concentrations than found in Fraser River fish. A comparable data base did not exist for chlorophenols, PAHs, PCBs, phthalate esters, or organochlorine pesticides. Such data would be a handy reference for future surveys, and should be expanded to include other fish species.

A time period of about eight years has existed between each of the three major surveys of fish from the lower Fraser River. This should be reduced, if possible, to a five year interval.

REFERENCES

AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Arlington, Virginia.

Garrett, C.L. Pacific and Yukon Region, Toxic Chemicals Profile. Environment Canada, Pacific and Yukon Region. Vancouver, B. C. September 1982.

Hall, K.J., V.K. Gugral, P. Parkinson, and T. Ma. Selected Organic Contaminants in Sediments and Fish From the Fraser River Estuary. Department of Civil Engineering and Westwater Research Centre. June 1986.

Inland Water Directorate. Guidelines for Surface Water Quality. Volume 2. Organic Chemical Substances. Phthalic Acid Esters. Ottawa Canada. 1983.

Johnston, N.T., L.J. Albright, T.G. Northcote, P.C. Oloffs, and K. Tsumura. 1975. Chlorinated Hydrocarbon Residues in Fishes from the Lower Fraser River. Report No. 9. Westwater Research Centre, University of British Columbia. Vancouver, B. C. November 1975.

Leah, T.D. The Production, Use, and Distribution of Phthalic Acid Esters in Canada. Environmental Contaminants Inventory Study No. 4. Inland Waters Directorate. Burlington, Ontario. 1977.

Levings, C. Unpublished Report to Department of Fisheries and Oceans. A Preliminary Investigation of Environmental Conditions Around Existing and Planned Fish Farm Sites in Sechelt and Salmon Inlets, B. C. February 1989.

Ministry of Environment. Water Quality Criteria for Mercury. Draft Report.

Nagpal, N.K. 1987. Water Quality Criteria for Lead. Ministry of Environment and Parks. Victoria, B. C. November 1987.

Northcote, T.G., N.T. Johnston, and K. Tsumura. 1975. Trace Metal Concentrations in Lower Fraser River Fishes. Technical Report No. 7. Westwater Research Centre, University of British Columbia. Vancouver, B.C.

Personal Communication. Mr. W.E. Erlebach, Inland Waters Directorate, Environment Canada, to Mr. L.G. Swain, Ministry of Environment. August 6, 1985.

Renberg, L. 1974. Ion exchange technique for the determination of chlorinated phenols and phenoxy acids in organic tissue, soil and water. Anal. Chem. 6: 459-461.

Singleton, H.J. 1983. Trace Metals and Selected Organic Contaminants in Fraser River Fish. MOE Technical Paper 2. Ministry of Environment. Victoria, B.C. April 1983.

Swain, L.G. 1983. Stormwater Monitoring of a Residential Catchment Area, Vancouver, B. C. Ministry of Environment. Victoria, B. C. June 1983.

Swain, L.G. 1986. A 1985 Survey of Metals, PCBs, and Chlorophenols in the Sediments, Benthic Organisms and Fish of the Lower Fraser River. Ministry of Environment and Parks. Victoria, B. C. June 1986.

Swain, L.G. and G.B. Holms. 1985. Fraser-Delta Area, Fraser River Sub-Basin From Kanaka Creek to the Mouth, Water Quality Assessment and Objectives. Ministry of Environment. Victoria, B.C. November 1985.

Tetra Tech. 1986. Analytical Methods for U.S. EPA Priority Pollutants and 301(h) Pesticides in Tissues from Estuarine and Marine Organisms. Report prepared for the U.S. Environmental Protection Agency. Contract No. 68-01-6938.

U.S. EPA. 1984. Guidelines Establishing Test Procedures for the Analyses of Pollutants under the Clean Water Act. 40 CFR Part 136. Federal Register 49: 209.

Working Committee on Fraser River Estuary Monitoring. 1984. Fraser River Estuary Monitoring, A Recommended Approach. Ministry of Environment. Victoria, B. C. March 1984.

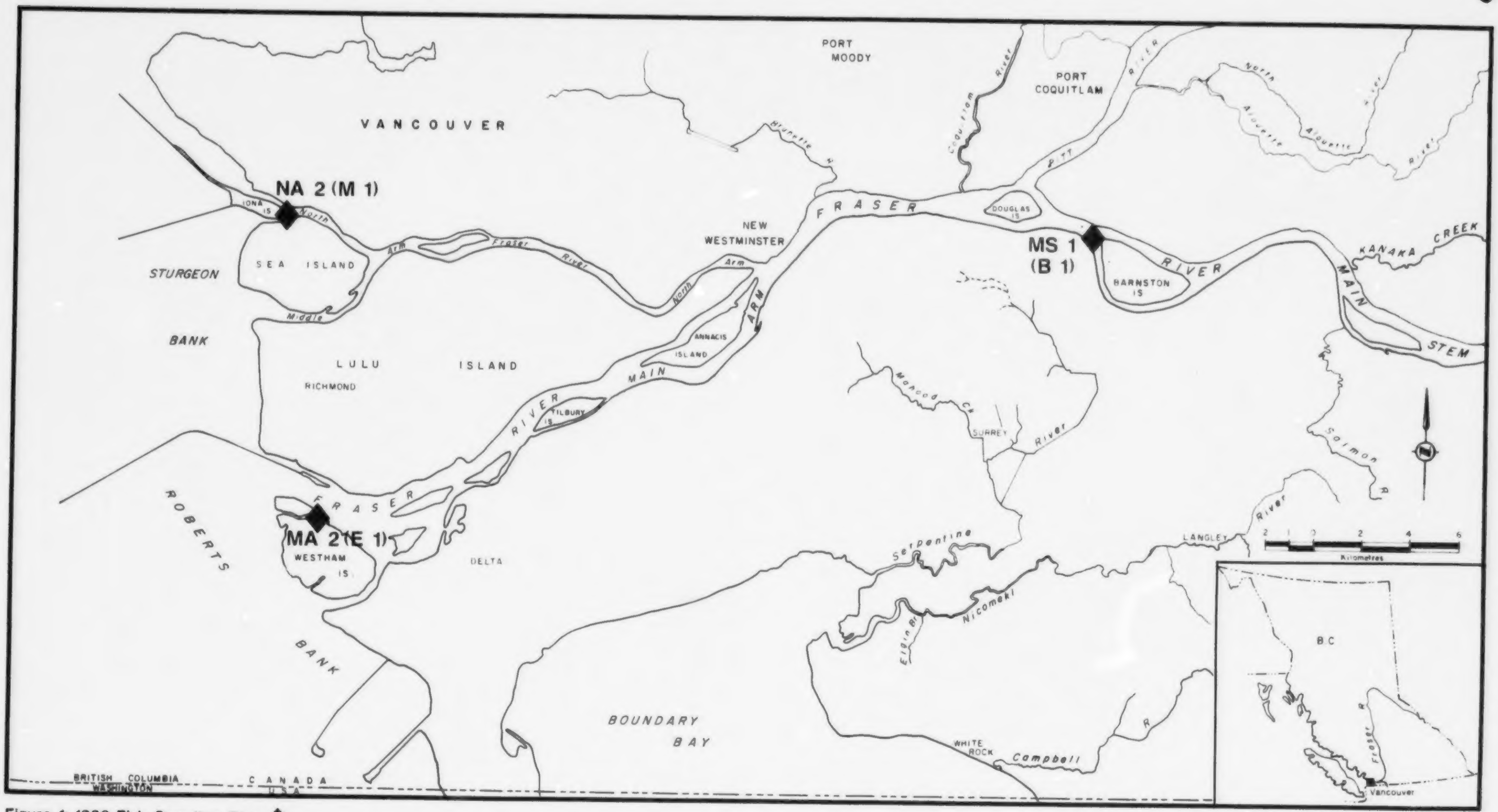

PORT MOODY
PORT COQUITLAM
VANCOUVER
Coquitlam River
Pitt River
North Alouette River
Alouette
NA 2 (M 1)
IONA IS
North Arm Fraser River
NEW WESTMINSTER
FRASER
DOUGLAS IS
MS 1 (B 1)
KANAKA CREEK
BARNSTON IS
RIVER
MAIN STEM
SEA ISLAND
STURGEON BANK
Middle
LULU ISLAND
RICHMOND
ANNACIS ISLAND
ARM
MAIN
RIVER
TILBURY IS
Surrey
River
Salmon R
LANGLEY
River
FRASER
MA 2 (E 1)
WESTHAM IS
DELTA
ROBERTS BANK
Serpentine
Nicomekl
Elgin Br
BOUNDARY BAY
WHITE ROCK
Campbell R
BRITISH COLUMBIA
WASHINGTON
CANADA
U.S.A.
2 1 0 2 4 6
Kilometres
B.C
Fraser R
Vancouver

Figure 1: 1988 Fish Sampling Sites ◆

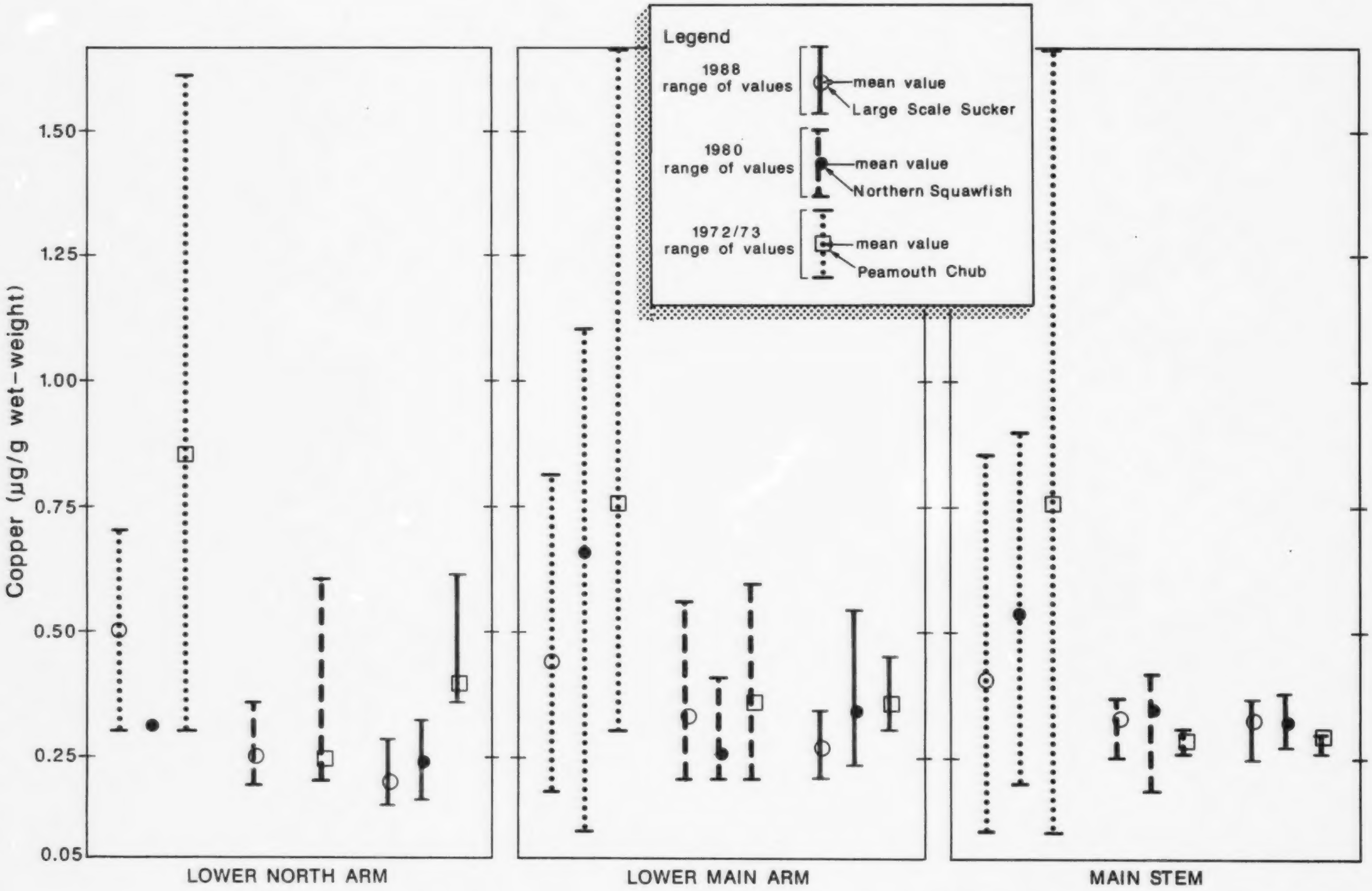


Figure 2: Copper concentrations in muscle from selected fish species: 1972–1988.

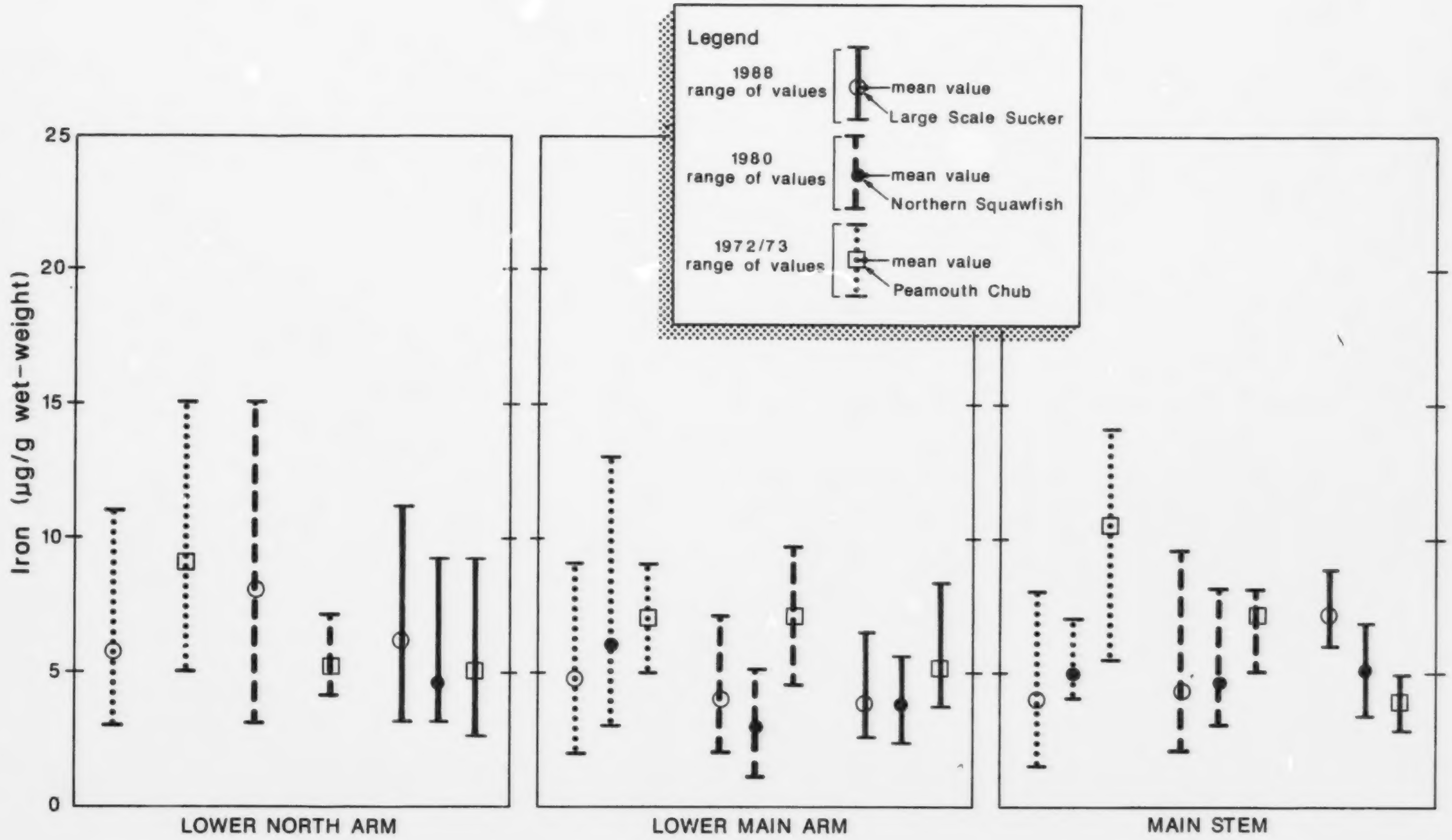


Figure 3 : Iron concentrations in muscle from selected fish species: 1972–1988.

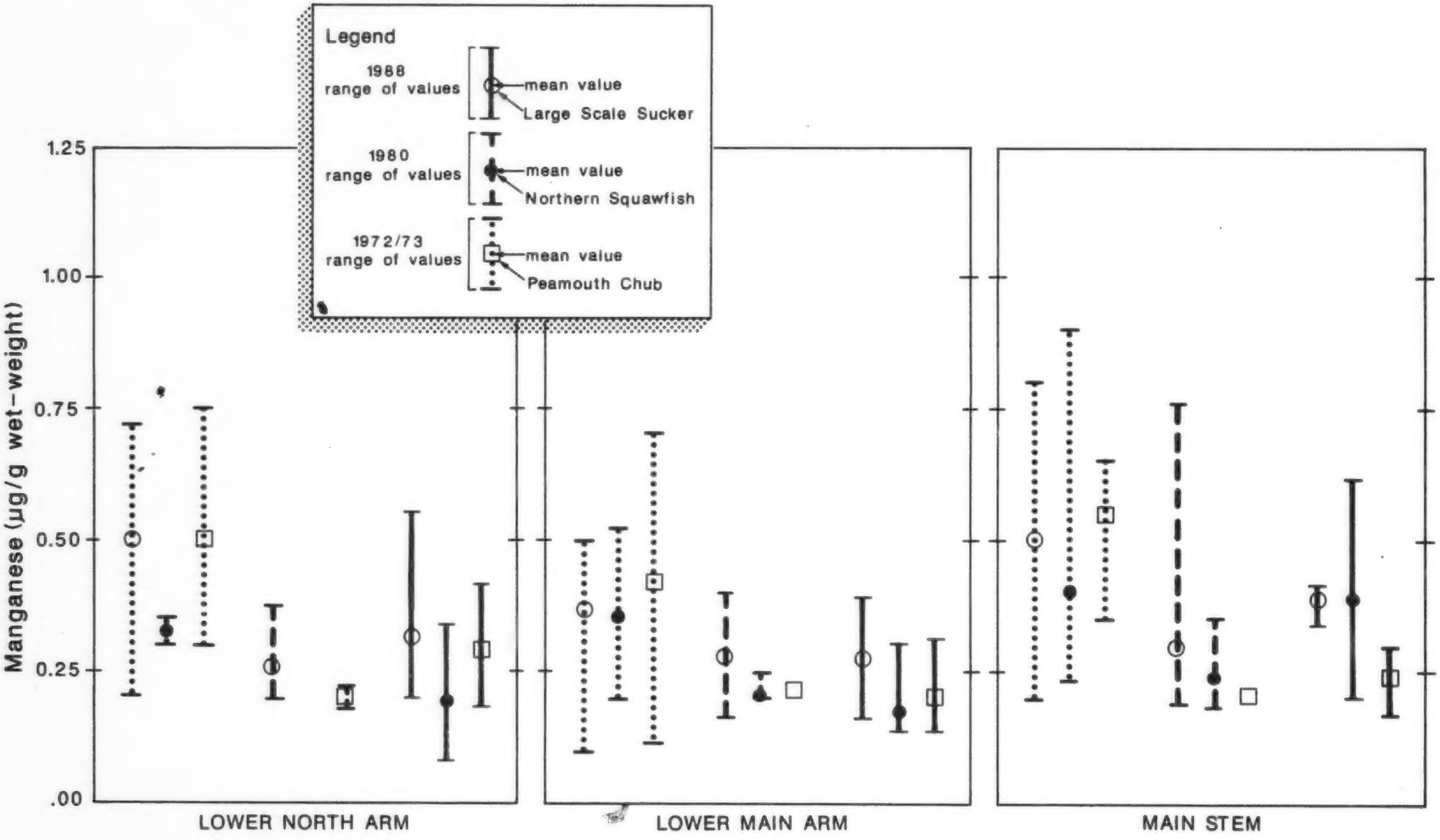


Figure 4 : Manganese concentrations in muscle from selected fish species: 1972–1988.

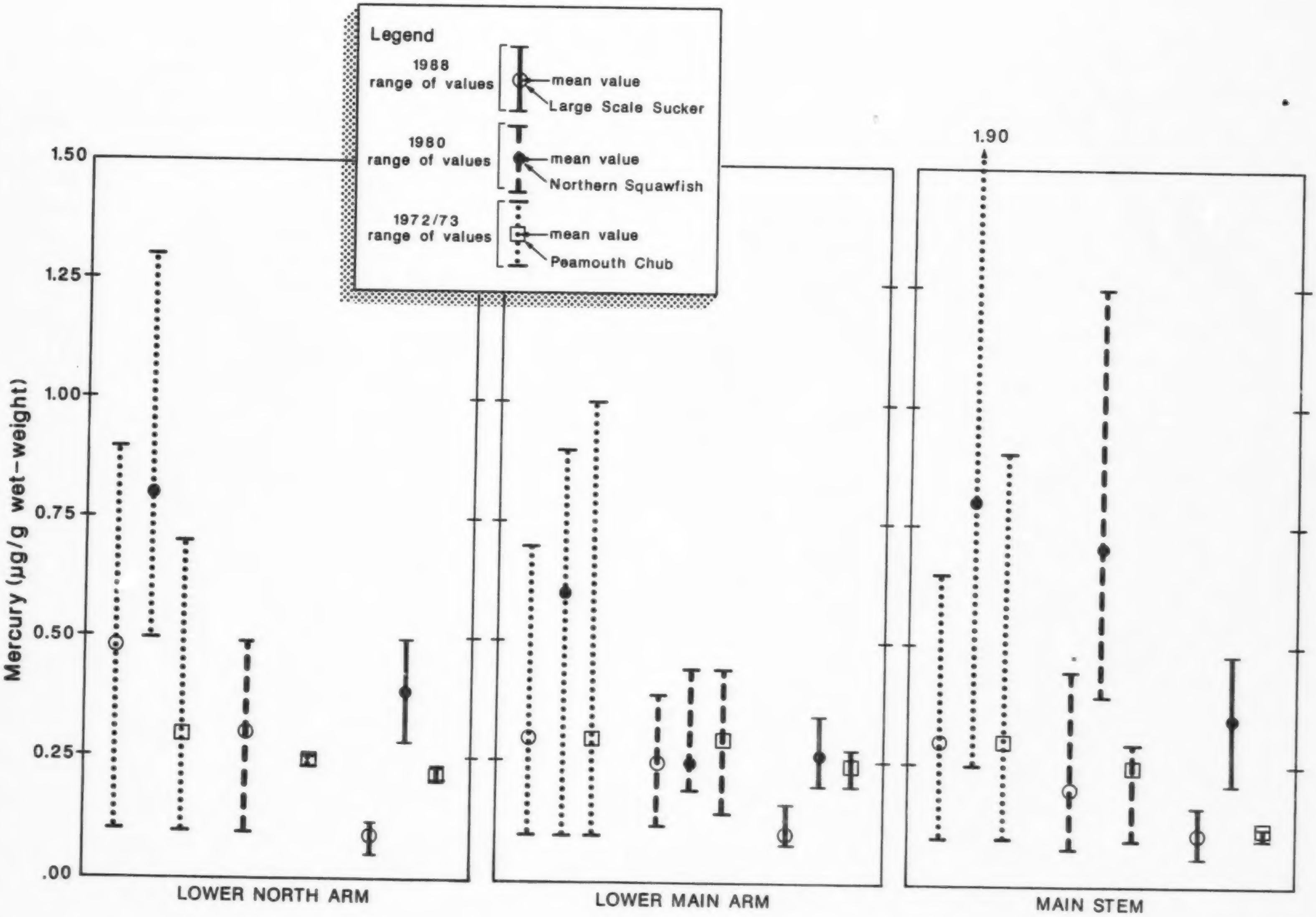


Figure 5 : Mercury concentrations in muscle from selected fish species: 1972–1988.

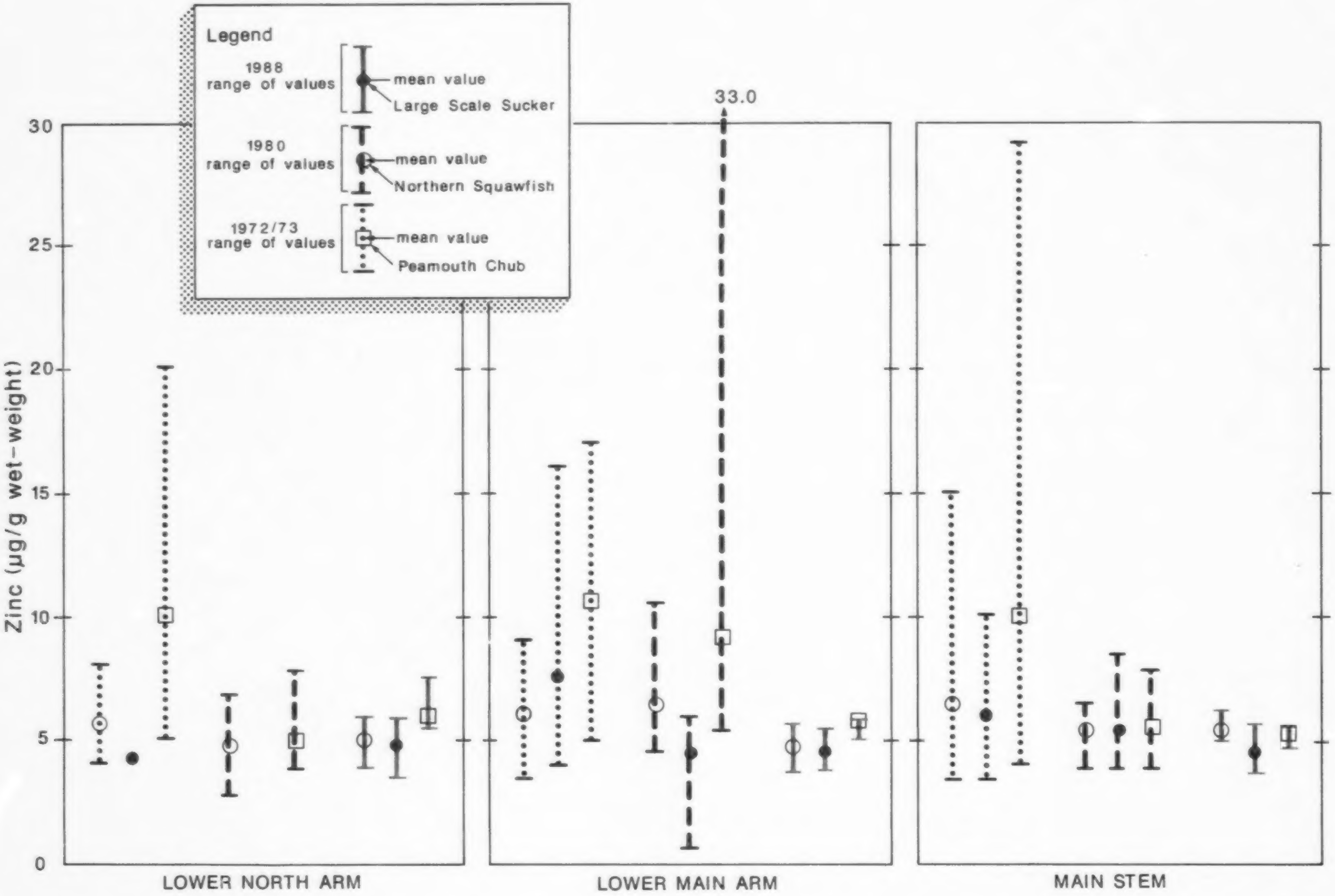


Figure 6 : Zinc concentrations in muscle from selected fish species: 1972–1988.

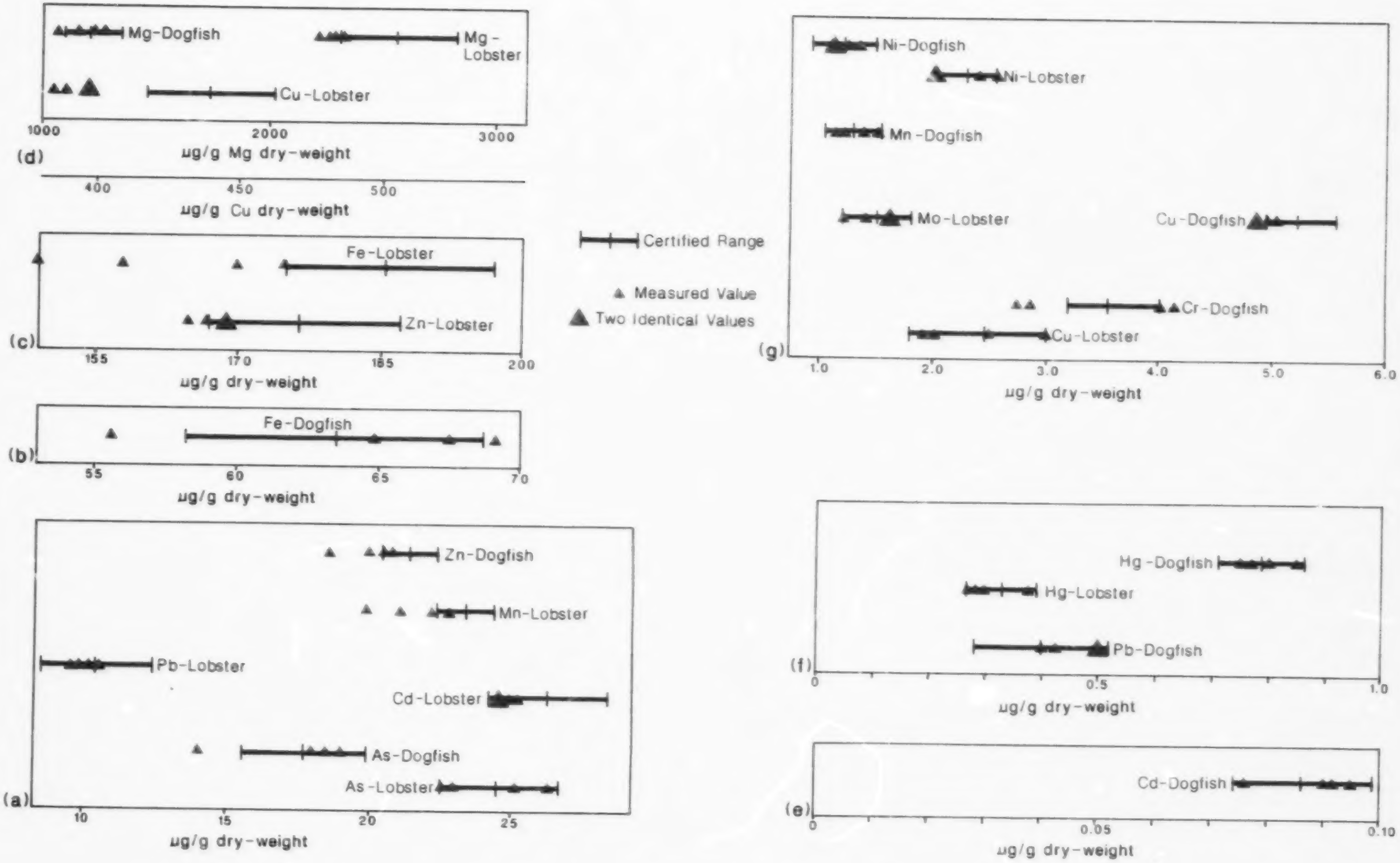
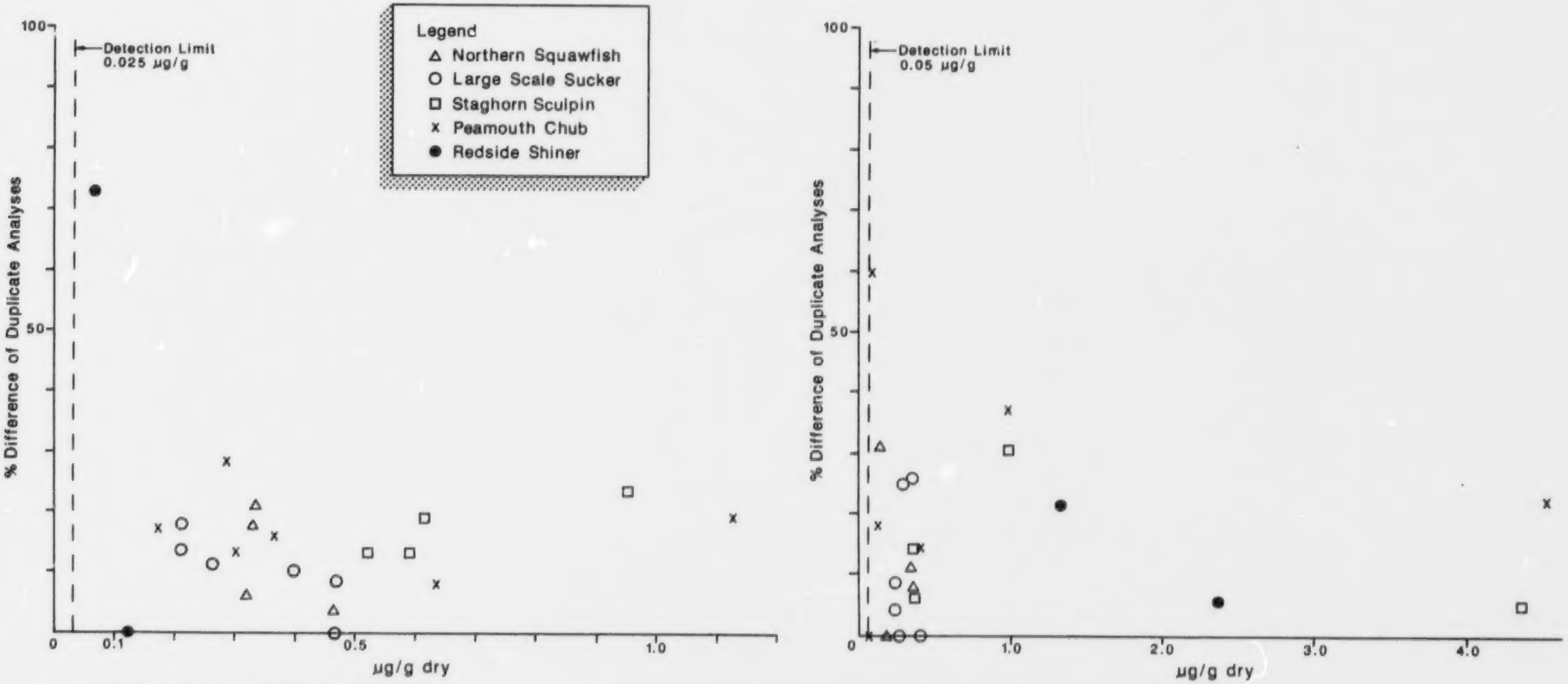


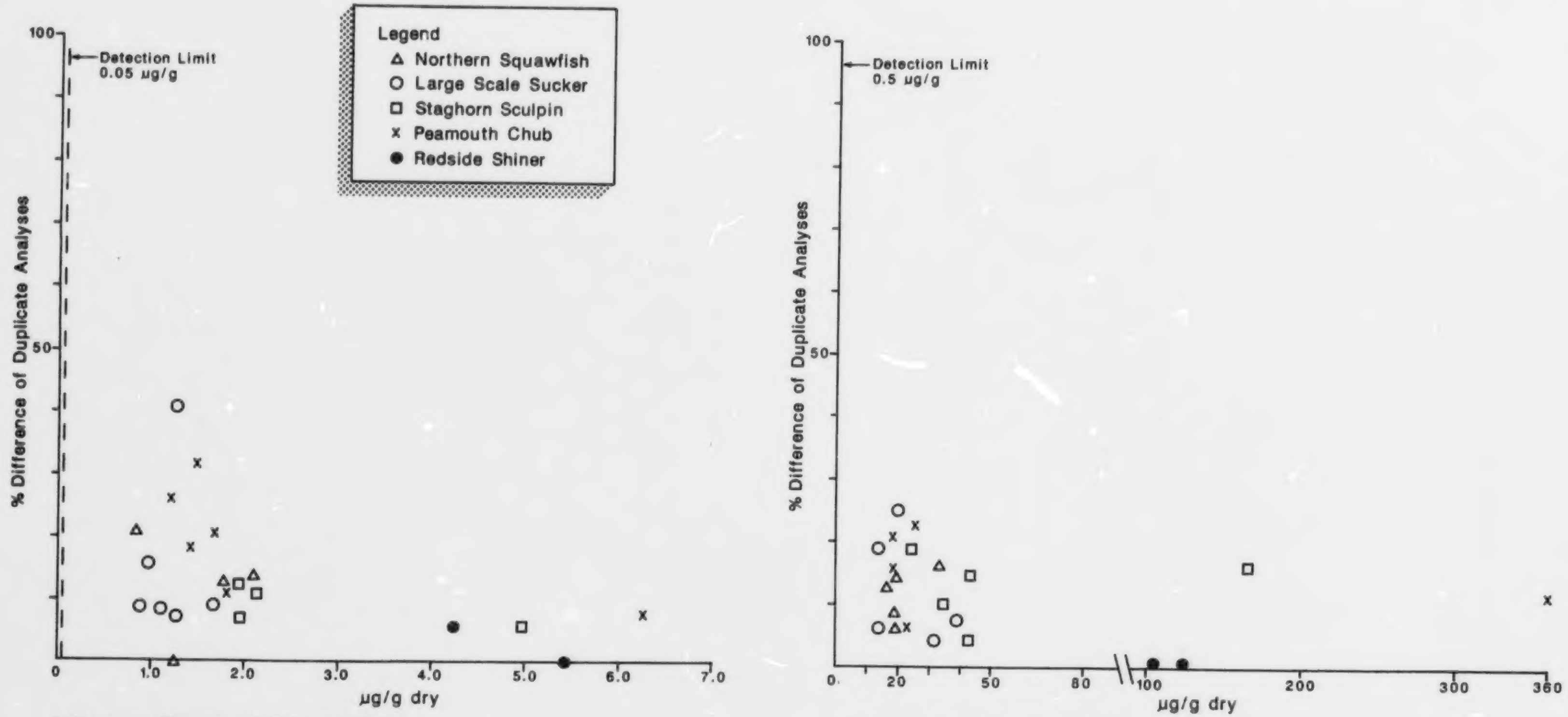
FIGURE 7 : QA/QC MEASUREMENTS FOR CERTIFIED MUSCLE TISSUES



(a) Lower Measured Arsenic Value

(b) Lower Measured Chromium Value

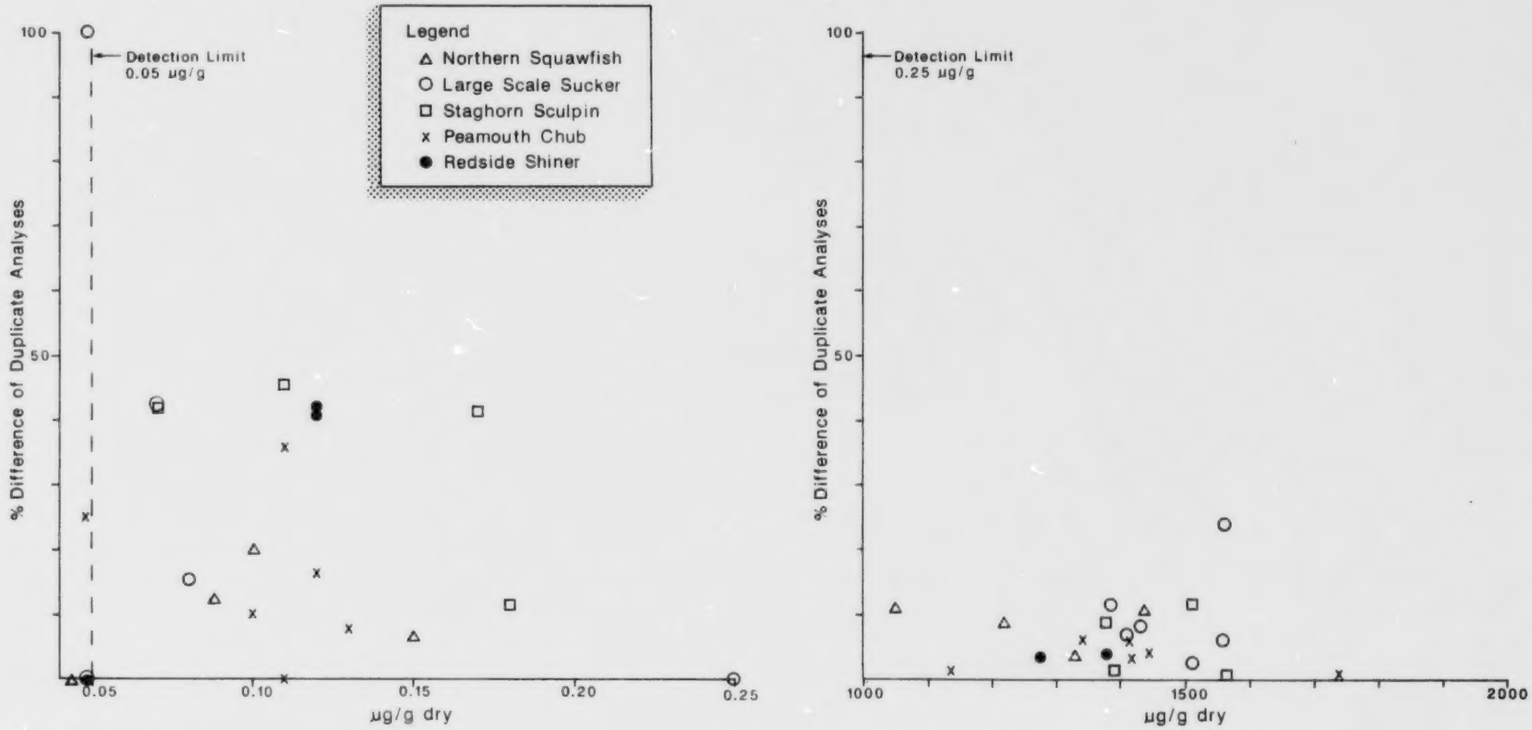
FIGURE 8: COMPARISON OF DUPLICATE ANALYSES FOR FISH MUSCLE TISSUES



(c) Lower Measured Copper Value

(d) Lower Measured Iron Value

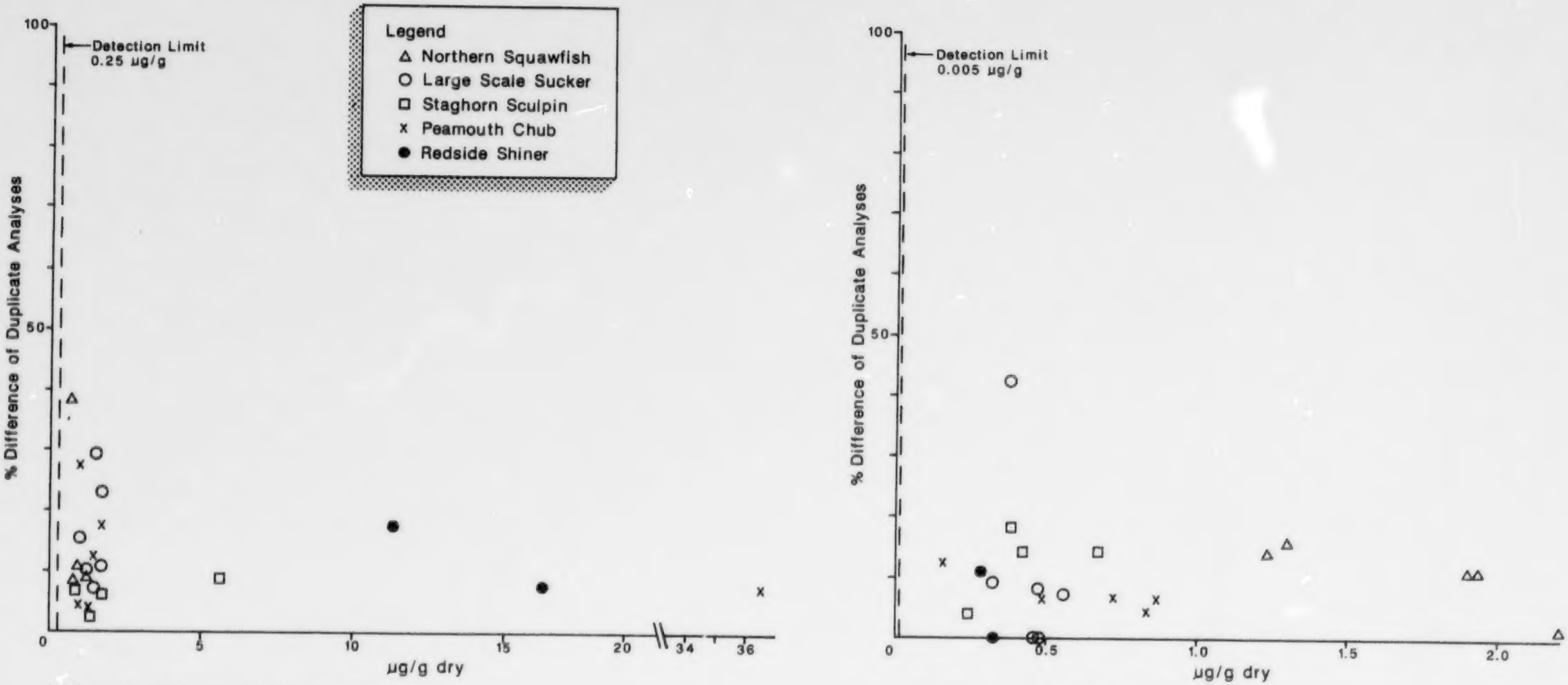
FIGURE 8 continued..



(e) Lower Measured Lead Value

(f) Lower Measured Magnesium Value

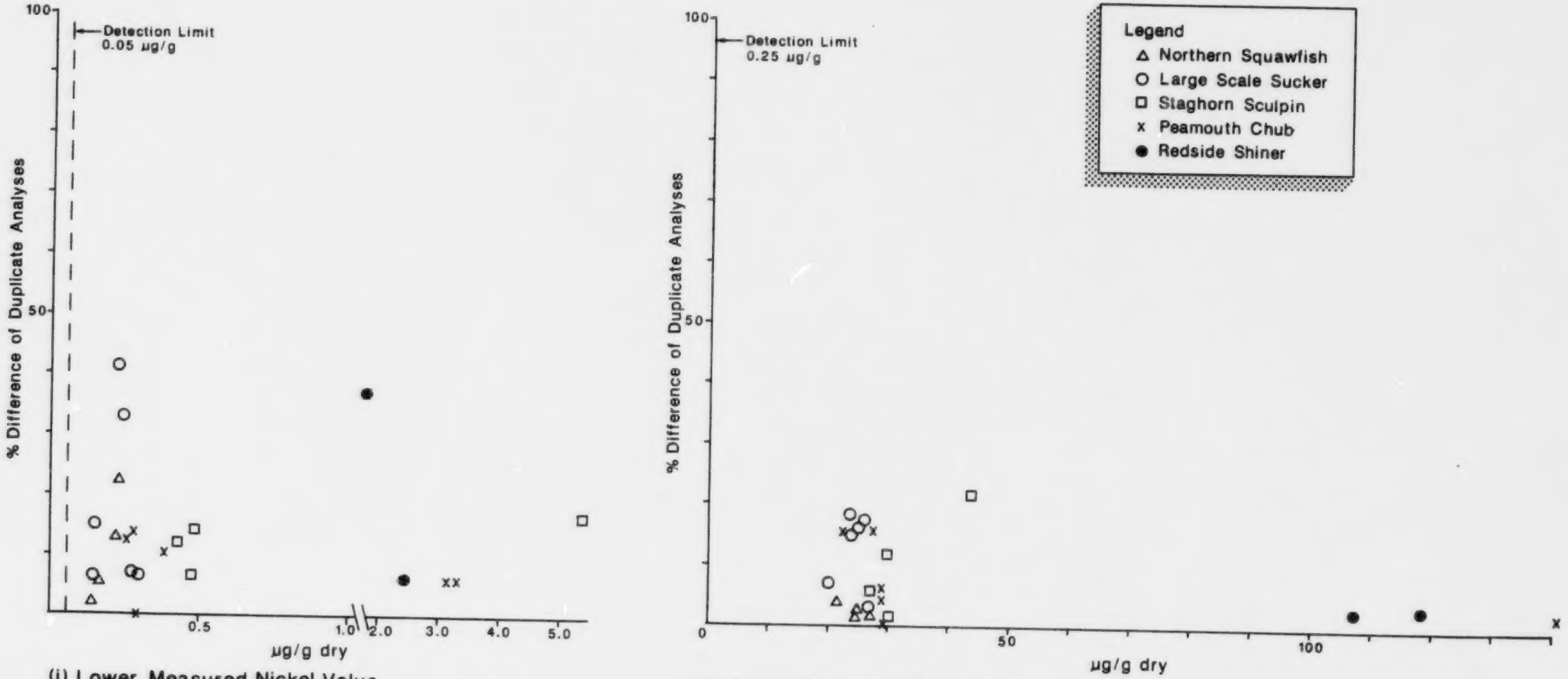
FIGURE 8 continued..



(g) Lower Measured Manganese Value

(h) Lower Measured Mercury Value

FIGURE 8 continued..



(i) Lower Measured Nickel Value

(j) Lower Measured Zinc Value

FIGURE 8 continued..

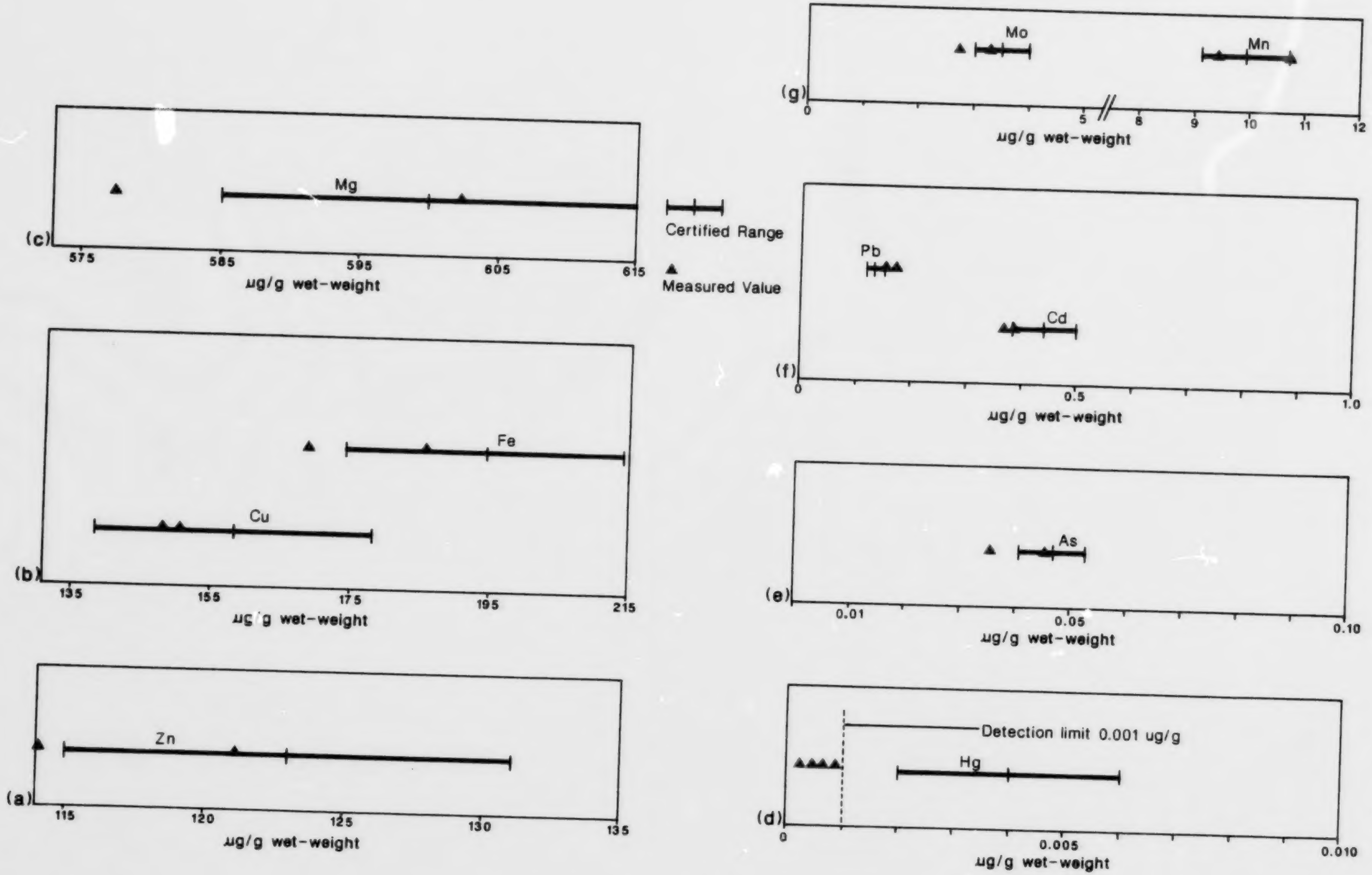


FIGURE 9 QA/QC DATA FOR CERTIFIED LIVER SAMPLE

TABLE 1
AVERAGE % MOISTURE CONTENT OF FISH MUSCLE FOR MEAN METAL VALUES

SPECIES	% MOISTURE		
	MAIN STEM MS-1	NORTH ARM NA-2	MAIN ARM MA-2
Largescale sucker	80.6	80.5	81.3
Northern Squawfish	81.7	80.3	81.4
Peamouth chub	82.1	79.1	80.8
Redside shiner	77.5	-	-
Staghorn sculpin	-	82.6	82.7
Starry flounder	-	83.8	83.7
Threespine stickleback	-	82.8	-

TABLE 2
DATA SUMMARY
METALS IN FISH MUSCLE

			ug/g (dry/wet weight)			Dry Wt.
ARSENIC	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	0.51/0.10	0.14/0.03	0.39/0.08	0.17
	NA2	17	0.75/0.15	0.11/0.02	0.37/0.07	0.14
	MA2	12	0.56/0.12	0.21/0.04	0.34/0.06	0.11
Northern Squawfish	MS1	6	0.43/0.08	0.14/0.03	0.29/0.05	0.12
	NA2	18	0.94/0.19	0.19/0.04	0.50/0.10	0.17
	MA2	10	0.56/0.10	0.17/0.03	0.31/0.06	0.13
Peamouth Chub	MS1	6	0.42/0.09	0.24/0.04	0.34/0.06	0.07
	NA2	13	0.50/0.10	0.17/0.04	0.34/0.07	0.11
	MA2	7	0.70/0.14	0.44/0.09	0.57/0.11	0.10
Redside Shiner	MS1	7	0.14/0.03	0.06/0.01	0.11/0.02	0.34
Staghorn Sculpin	NA2	7	1.55/0.31	0.69/0.10	0.96/0.17	0.31
	MA2	7	1.46/0.24	0.52/0.09	0.89/0.15	0.37
Starry Flounder	NA2	3	2.42/0.57	0.33/0.04	1.16/0.19	1.11
	MA2	8	2.18/0.40	1.12/0.18	1.52/0.25	0.31
Threespine Stickleback	NA2	2	0.71/0.12	0.35/0.06	0.53/0.09	-
CADMIUM ND : 0.025/0.005						
Largescale Sucker	MS1	4	0.09/0.02	ND	-	-
	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	6	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	7	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	7	ND	ND	ND	-
	MA2	7	0.076/0.014	ND	-	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	0.20/0.03	ND	0.10/0.02	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 2 (CONTINUED)

			ug/g (dry/wet weight)			Dry Wt.
CHROMIUM	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	4	0.38/0.07	0.20/0.04	0.27/0.05	0.08
Sucker	NA2	17	0.75/0.14	0.31/0.06	0.41/0.08	0.11
	MA2	12	1.16/0.27	0.22/0.04	0.34/0.06	0.26
Northern	MS1	6	0.38/0.07	0.04/0.007	0.18/0.03	0.12
Squawfish	NA2	18	0.84/0.17	0.28/0.06	0.41/0.08	0.29
	MA2	10	0.30/0.06	0.17/0.03	0.23/0.04	0.05
Peamouth	MS1	6	0.16/0.03	0.05/0.01	0.10/0.02	0.04
Chub	NA2	13	1.35/0.30	0.40/0.10	0.73/0.16	0.29
	MA2	7	0.47/0.09	<0.05/0.01	0.22/0.04	0.15
Redside Shiner	MS1	7	2.92/0.64	0.85/0.19	1.91/0.43	0.72
Staghorn	NA2	7	4.59/0.70	0.98/0.18	2.76/0.48	1.53
Sculpin	MA2	7	0.55/0.09	0.18/0.03	0.35/0.06	0.13
Starry	NA2	3	20.2/2.50	0.68/0.16	12.6/2.05	10.5
Flounder	MA2	8	11.1/2.03	3.52/0.55	6.79/1.11	2.65
Threespine Stickleback	NA2	2	8.20/1.41	6.38/1.10	7.29/1.26	-
COPPER						
Largescale	MS1	4	1.86/0.37	1.31/0.25	1.70/0.33	0.26
Sucker	NA2	17	1.46/0.28	0.71/0.15	1.03/0.20	0.16
	MA2	12	1.76/0.34	1.04/0.21	1.45/0.27	0.27
Northern	MS1	6	2.03/0.38	1.53/0.27	1.74/0.32	0.19
Squawfish	NA2	18	1.73/0.32	0.82/0.16	1.18/0.24	0.27
	MA2	10	2.42/0.54	1.32/0.23	1.82/0.34	0.33
Peamouth	MS1	6	1.90/0.30	1.25/0.26	1.60/0.29	0.26
Chub	NA2	13	2.93/0.62	1.40/0.35	1.85/0.39	0.42
	MA2	7	2.15/0.45	1.66/0.30	1.91/0.37	0.18
Redside Shiner	MS1	7	5.39/1.18	3.43/0.83	4.62/1.04	0.68
Staghorn	NA2	7	5.20/0.79	1.89/0.35	2.91/0.50	1.48
Sculpin	MA2	7	2.34/0.44	1.62/0.27	2.03/0.35	0.26
Starry	NA2	3	8.74/1.08	1.08/0.26	5.82/0.94	4.14
Flounder	MA2	8	7.48/1.17	4.24/0.70	5.60/0.91	1.23
Threespine Stickleback	NA2	2	9.20/1.58	8.37/1.44	8.79/1.51	-

TABLE 2 (CONTINUED)

				ug/g (dry/wet weight)			Dry Wt.
IRON		Site	n	Max	Min	Mean	Std Dev
	Largescale	MS1	4	44.9/8.8	31.3/5.9	36.6/7.09	6.10
	Sucker	NA2	17	56.7/11.2	20.4/3.75	35.1/6.84	9.97
		MA2	12	31.2/6.33	13.2/2.47	20.4/3.81	6.86
	Northern	MS1	6	37.8/6.84	18.1/3.24	28.1/5.15	8.32
	Squawfish	NA2	18	40.9/7.73	14.7/3.04	22.1/4.34	6.96
		MA2	10	30.6/5.45	13.3/2.33	20.8/3.87	5.30
	Peamouth	MS1	6	27.7/4.74	18.4/2.89	22.1/3.96	3.37
	Chub	NA2	13	34.9/7.54	15.9/3.13	24.0/5.02	5.68
		MA2	7	45.2/8.23	19.8/3.58	26.4/5.07	8.51
	Redside Shiner	MS1	7	166/36.2	76.7/18.5	113/25.5	28.2
	Staghorn	NA2	7	190/28.9	23.2/4.15	69.1/12.0	74.2
	Sculpin	MA2	7	44.3/7.5	16.4/3.00	32.0/5.53	10.7
	Starry	NA2	3	1261/156	22.5/5.33	811/131	685
	Flounder	MA2	8	704/129	360/56.9	477/77.8	110
	Threespine Stickleback	NA2	2	419/72.1	346/59.5	383/65.8	-
LEAD ND : 0.05/0.01							
	Largescale	MS1	4	0.11/0.02	0.07/0.01	0.09/0.02	0.02
	Sucker	NA2	17	0.25/0.05	0.08/0.02	0.16/0.03	0.06
		MA2	12	0.13/0.03	ND	-	-
	Northern	MS1	6	0.16/0.03	0.13/0.02	0.15/0.03	0.01
	Squawfish	NA2	18	0.31/0.06	0.09/0.02	0.18/0.03	0.07
		MA2	10	0.08/0.01	ND	-	-
	Peamouth	MS1	6	0.14/0.03	0.12/0.02	0.13/0.02	0.98
	Chub	NA2	13	0.44/0.10	0.07/0.01	0.22/0.05	0.25
		MA2	7	0.07/0.01	ND	0.05/0.01	0.02
	Redside Shiner	MS1	7	0.17/0.04	0.11/0.03	0.13/0.03	0.03
	Staghorn	NA2	7	0.33/0.07	0.15/0.03	0.21/0.04	0.06
	Sculpin	MA2	7	0.16/0.03	0.07/0.01	0.10/0.02	0.03
	Starry	NA2	3	0.67/0.08	0.14/0.03	0.44/0.07	0.27
	Flounder	MA2	8	0.18/0.03	0.11/0.02	0.14/0.02	0.02
	Threespine Stickleback	NA2	2	0.28/0.05	0.25/0.04	0.27/0.05	-

TABLE 2 (CONTINUED)

			ug/g (dry/wet weight)			Dry Wt.
MAGNESIUM	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	1650/312	1558/294	1599/310	39.1
	NA2	17	1827/336	1160/235	1489/290	180
	MA2	12	1935/373	1254/255	1530/286	165
Northern Squawfish	MS1	6	1511/277	1274/238	1390/254	84.5
	NA2	18	1816/354	806/147	1272/251	281
	MA2	10	1435/251	1199/239	1325/246	81.7
Peamouth Chub	MS1	6	1511/423	1397/240	1441/258	41.2
	NA2	13	1751/285	1158/292	1385/289	154
	MA2	7	1648/300	1335/278	1454/279	109
Redside Shiner	MS1	7	1441/314	1086/262	1329/299	124
Staghorn Sculpin	NA2	7	1686/309	1225/219	1457/254	143
	MA2	7	1571/295	1364/250	1462/253	84.6
Starry Flounder	NA2	3	2088/259	945/224	1551/251	575
	MA2	8	1830/335	1528/254	1706/278	103
Threespine Stickleback	NA2	2	1969/337	1719/296	1844/317	-
MANGANESE						
Largescale Sucker	MS1	4	2.19/0.41	1.78/0.34	2.02/0.39	0.19
	NA2	17	2.61/0.54	0.96/0.20	1.64/0.32	0.52
	MA2	12	2.04/0.39	0.96/0.16	1.47/0.27	0.32
Northern Squawfish	MS1	6	3.33/0.62	1.09/0.20	2.08/0.38	1.01
	NA2	18	1.76/0.34	0.36/0.07	0.95/0.19	0.43
	MA2	10	1.73/0.30	0.57/0.13	0.92/0.17	0.35
Peamouth Chub	MS1	6	1.69/0.29	1.08/0.17	1.34/0.24	0.26
	NA2	13	1.90/0.42	0.87/0.19	1.35/0.28	0.37
	MA2	7	1.68/0.31	0.70/0.13	1.04/0.20	0.32
Redside Shiner	MS1	7	20.1/4.38	10.2/2.46	14.6/3.29	3.48
Staghorn Sculpin	NA2	7	6.22/0.95	0.71/0.13	2.35/0.41	2.47
	MA2	7	1.79/0.30	0.86/0.16	1.33/0.23	0.33
Starry Flounder	NA2	3	38.9/4.82	0.97/0.23	24.1/3.91	20.3
	MA2	8	52.4/9.59	26.4/4.38	36.0/5.83	93.4
Threespine Stickleback	NA2	2	44.1/7.59	39.8/6.85	42.0/7.22	-

TABLE 2 (CONTINUED)

			ug/g (dry/wet weight)			Dry Wt.
MERCURY	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	0.85/0.17	0.32/0.06	0.55/0.11	0.26
	NA2	17	0.58/0.12	0.28/0.05	0.40/0.08	0.10
	MA2	12	0.87/0.17	0.47/0.08	0.54/0.10	0.11
Northern Squawfish	MS1	6	2.57/0.48	1.10/0.21	1.89/0.35	0.55
	NA2	18	2.70/0.50	1.39/0.29	1.98/0.39	0.32
	MA2	10	1.75/0.35	1.11/0.20	1.44/0.27	0.20
Peamouth Chub	MS1	6	0.77/0.12	0.49/0.10	0.65/0.12	0.12
	NA2	13	1.32/0.22	0.82/0.21	1.08/0.23	0.17
	MA2	7	1.48/0.28	0.97/0.20	1.25/0.24	0.18
Redside Shiner	MS1	7	0.32/0.07	0.16/0.04	0.27/0.06	0.06
Staghorn Sculpin	NA2	7	0.77/0.14	0.38/0.06	0.56/0.10	0.14
	MA2	7	0.57/0.09	0.23/0.04	0.41/0.07	0.13
Starry Flounder	NA2	3	0.54/0.13	0.18/0.02	0.32/0.05	0.19
	MA2	8	0.33/0.05	0.13/0.02	0.22/0.04	0.08
Threespine Stickleback	NA2	2	0.20/0.03	0.20/0.03	0.20/0.03	-
MOLYBDENUM						
ND : 0.25/0.05						
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	6	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	7	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	7	0.29/0.04	ND	ND	-
	MA2	7	ND	ND	ND	-
Starry Flounder	NA2	3	1.24/0.15	ND	0.98/0.12+	-
	MA2	8	0.59/0.11	0.26/0.04	0.36/0.05	0.10
Threespine Stickleback	NA2	2	1.36/0.23	1.28/0.22	1.32/0.23	-

+ Median Value

TABLE 2 (CONTINUED)

			µg/g (dry/wet weight)			Dry Wt.
NICKEL	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	0.43/0.08	0.28/0.06	0.33/0.06	0.07
	NA2	17	0.44/0.08	0.11/0.02	0.22/0.04	0.09
	MA2	12	0.40/0.07	0.15/0.03	0.26/0.05	0.09
Northern Squawfish	MS1	6	0.42/0.08	0.22/0.04	0.31/0.06	0.08
	NA2	18	0.46/0.09	0.09/0.02	0.20/0.04	0.09
	MA2	10	0.48/0.09	0.22/0.05	0.28/0.05	0.07
Peamouth Chub	MS1	6	0.43/0.09	0.21/0.04	0.32/0.06	0.08
	NA2	13	5.57/1.08	0.23/0.05	1.25/0.26	1.72
	MA2	7	0.35/0.06	0.18/0.03	0.24/0.05	0.06
Redside Shiner	MS1	7	2.65/0.58	0.94/0.21	1.84/0.41	0.70
Staghorn Sculpin	NA2	7	6.31/0.96	0.49/0.09	2.83/0.49	2.44
	MA2	7	0.57/0.10	0.32/0.05	0.43/0.08	0.09
Starry Flounder	NA2	3	21.5/2.67	0.43/0.10	12.8/2.08	11.0
	MA2	8	6.66/1.22	1.83/0.29	3.90/0.64	1.38
Threespine Stickleback	NA2	2	15.3/2.63	12.8/2.20	14.1/2.42	-
ZINC						
Largescale Sucker	MS1	4	31.4/6.15	25.0/5.03	27.2/5.27	2.88
	NA2	17	32.4/6.64	20.1/4.02	27.5/5.36	3.86
	MA2	12	31.6/5.85	18.6/3.92	25.2/4.71	3.77
Northern Squawfish	MS1	6	30.8/5.79	20.6/3.85	24.5/4.47	3.41
	NA2	18	31.6/5.91	20.5/3.73	25.4/5.00	2.34
	MA2	10	29.4/5.59	21.4/3.98	23.9/4.44	2.49
Peamouth Chub	MS1	6	32.7/5.62	27.8/4.75	29.5/5.28	1.75
	NA2	13	35.0/7.56	22.6/5.70	28.2/5.89	4.08
	MA2	7	31.8/5.95	26.4/5.04	29.6/5.69	1.84
Redside Shiner	MS1	7	140/30.5	103/24.8	118/26.6	12.8
Staghorn Sculpin	NA2	7	52.6/8.00	28.3/4.78	36.1/6.27	8.73
	MA2	7	32.5/5.27	26.3/4.44	29.3/5.07	2.19
Starry Flounder	NA2	3	144/17.9	37.5/8.89	104/16.8	57.9
	MA2	8	147/26.9	101/16.77	129/21.0	20.9
Threespine Stickleback	NA2	2	195/33.5	172/29.6	184/31.6	-

TABLE 3
DATA SUMMARY
METAL VALUES IN FISH LIVERS

ARSENIC
ND : 0.005

	Site	n	ug/g (wet weight)			
			Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.026	-	-	-
	NA2	6	0.11	ND	0.051	0.225
	MA2	4	0.23	0.079	0.129	0.069
Northern Squawfish	MS1	1	0.10	0.035	0.068	-
	NA2	8	0.42	0.047	0.256	0.135
	MA2	4	0.22	0.089	0.170	0.056
Peamouth Chub	MS1	1	0.12	-	-	-
	NA2	9	0.42	0.071	0.25	0.141
	MA2	4	0.26	0.16	0.21	0.046
Staghorn Sculpin	NA2	2	0.26	0.16	0.21	-
	MA2	3	0.23	0.16	0.187	0.038
Starry Flounder	NA2	1	0.45	-	-	-
	MA2	1	0.16	-	-	-

CADMIUM
ND : 0.005

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.051	-	-	-
	NA2	6	0.13	ND	0.06	0.044
	MA2	4	0.22	0.030	0.092	0.088
Northern Squawfish	MS1	2	0.068	0.026	0.047	-
	NA2	8	0.037	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	0.13	-	-	-
	NA2	9	0.10	0.030	0.060	0.020
	MA2	4	0.13	0.051	0.073	0.038
Staghorn Sculpin	NA2	2	0.27	0.077	0.174	-
	MA2	3	0.19	0.12	0.147	0.038
Starry Flounder	NA2	1	0.052	-	-	-
	MA2	1	0.19	-	-	-

TABLE 3 (CONTINUED)

CHROMIUM			ug/g (wet weight)			
ND : 0.01	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	0.14	-	-	-
Sucker	NA2	6	0.11	0.05	0.085	0.025
	MA2	4	0.27	ND	0.148	0.116
Northern	MS1	2	0.13	0.12	0.125	-
Squawfish	NA2	8	0.08	ND	0.046	0.024
	MA2	4	0.12	0.05	0.078	0.030
Peamouth	MS1	1	0.44	-	-	-
Chub	NA2	9	0.37	ND	0.12	0.122
	MA2	4	0.09	0.05	0.065	0.017
Staghorn	NA2	2	0.11	ND	-	-
Sculpin	MA2	3	0.28	0.13	0.20	0.076
Starry	NA2	1	0.07	-	-	-
Flounder	MA2	1	0.21	-	-	-

COPPER

Largescale	MS1	1	3.71	-	-	-
Sucker	NA2	6	4.67	1.58	3.75	1.15
	MA2	4	11.0	3.34	6.73	3.42
Northern	MS1	2	5.27	4.06	4.67	-
Squawfish	NA2	8	6.52	2.81	5.08	1.44
	MA2	4	4.23	2.76	3.45	0.69
Peamouth	MS1	1	2.67	-	-	-
Chub	NA2	9	6.56	1.67	3.06	1.43
	MA2	4	4.49	2.38	3.08	0.95
Staghorn	NA2	6	6.82	6.40	6.61	-
Sculpin	MA2	3	14.6	6.75	9.77	4.23
Starry	NA2	1	9.67	-	-	-
Flounder	MA2	1	4.87	-	-	-

TABLE 3 (CONTINUED)

IRON		Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
	Largescale	MS1	1	155	-	-	-
	Sucker	NA2	6	145	70.3	111	30.7
		MA2	4	178	66.0	119	48.2
	Northern	MS1	2	121	90.3	106	-
	Squawfish	NA2	8	145	90.1	117	18.1
		MA2	4	142	101	118	18.7
	Peamouth	MS1	1	158	-	-	-
	Chub	NA2	9	120	49.4	96.1	24.8
		MA2	4	111	88	97.7	9.88
	Staghorn	NA2	6	96.9	82	89.5	-
	Sculpin	MA2	3	131	88.6	109	21.3
	Starry	NA2	1	166	-	-	-
	Flounder	MA2	1	165	-	-	-

LEAD	ND : 0.01						
	Largescale	MS1	1	0.05	-	-	-
	Sucker	NA2	6	0.09	0.05	0.068	0.018
		MA2	4	0.20	ND	0.078	0.084
	Northern	MS1	2	0.05	ND	-	-
	Squawfish	NA2	8	0.17	ND	0.086	0.047
		MA2	4	ND	ND	ND	-
	Peamouth	MS1	1	0.07	-	-	-
	Chub	NA2	9	0.08	ND	0.044	0.027
		MA2	4	ND	ND	ND	-
	Staghorn	NA2	2	0.08	0.07	0.075	-
	Sculpin	MA2	3	0.16	0.09	0.12	0.036
	Starry	NA2	1	ND	-	-	-
	Flounder	MA2	1	ND	-	-	-

TABLE 3 (CONTINUED)

MAGNESIUM	Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
Largescale	MS1	1	112	-	-	-
Sucker	NA2	6	183	109	158	29.0
	MA2	4	235	142	171	43.3
Northern	MS1	1	141	110	125	-
Squawfish	NA2	8	149	120	133	10.1
	MA2	4	144	138	141	2.75
Peamouth	MS1	1	171	-	-	-
Chub	NA2	9	143	98.6	124	15.6
	MA2	4	149	119	129	13.4
Staghorn	NA2	2	136	130	133	-
Sculpin	MA2	3	156	135	148	11.2
Starry	NA2	1	124	-	-	-
Flounder	MA2	1	112	-	-	-
MANGANESE						
Largescale	MS1	1	2.57	-	-	-
Sucker	NA2	6	2.62	0.68	1.54	0.81
	MA2	4	15.2	2.24	6.00	6.15
Northern	MS1	1	0.95	0.93	0.94	-
Squawfish	NA2	8	0.89	0.50	0.69	0.16
	MA2	4	1.05	0.60	0.83	0.19
Peamouth	MS1	1	1.28	-	-	-
Chub	NA2	9	3.78	0.74	2.11	1.46
	MA2	4	0.85	0.70	0.81	0.075
Staghorn	NA2	2	0.96	0.85	0.905	-
Sculpin	MA2	3	1.53	1.02	1.24	0.26
Starry	NA2	1	0.60	-	-	-
Flounder	MA2	1	0.76	-	-	-

TABLE 3 (CONTINUED)

			ug/g (wet weight)			
MERCURY	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.049	-	-	-
	NA2	6	0.070	0.014	0.028	0.021
	MA2	4	0.044	0.013	0.030	0.013
Northern Squawfish	MS1	2	0.093	0.042	0.068	-
	NA2	8	0.18	0.069	0.118	0.036
	MA2	4	0.078	0.052	0.068	0.012
Peamouth Chub	MS1	1	0.24	-	-	-
	NA2	9	0.17	0.071	0.10	0.034
	MA2	4	0.097	0.081	0.090	0.007
Staghorn Sculpin	NA2	2	0.48	0.17	0.325	-
	MA2	3	0.16	0.12	0.14	0.02
Starry Flounder	NA2	1	0.18	-	-	-
	MA2	1	0.086	-	-	-

MOLYBDENUM ND : 0.05

Largescale Sucker	MS1	1	0.22	-	-	-
	NA2	6	0.20	0.10	0.16	0.036
	MA2	4	0.22	0.16	0.19	0.025
Northern Squawfish	MS1	2	0.13	0.09	0.11	-
	NA2	8	ND	ND	ND	-
	MA2	4	0.11	0.07	0.093	0.017
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.20	0.12	0.154	0.026
	MA2	4	0.15	0.12	0.138	0.015
Staghorn Sculpin	NA2	2	0.10	ND	0.075	-
	MA2	3	0.11	ND	0.087	0.032
Starry Flounder	NA2	1	0.22	-	-	-
	MA2	1	0.18	-	-	-

TABLE 3 (CONTINUED)

NICKEL			ug/g (wet weight)			
ND : 0.01	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.21	-	-	-
	NA2	6	0.20	0.09	0.145	0.054
	MA2	4	0.27	0.12	0.183	0.068
Northern Squawfish	MS1	2	0.08	0.07	0.075	-
	NA2	8	0.12	ND	0.076	0.033
	MA2	4	0.07	0.05	0.06	0.008
Peamouth Chub	MS1	1	0.12	-	-	-
	NA2	9	0.24	ND	0.123	0.086
	MA2	4	0.06	ND	0.043	0.022
Staghorn Sculpin	NA2	2	0.12	0.07	0.095	-
	MA2	3	0.28	0.13	0.20	0.076
Starry Flounder	NA2	1	0.10	-	-	-
	MA2	1	0.11	-	-	-

ZINC

Largescale Sucker	MS1	1	15.1	-	-	-
	NA2	6	28.5	15.1	22.5	4.75
	MA2	4	28.0	22.9	25.6	2.60
Northern Squawfish	MS1	2	17.5	12.8	15.2	-
	NA2	8	19.3	12.9	15.5	1.95
	MA2	4	19.9	12.7	15.5	3.29
Peamouth Chub	MS1	1	18.1	-	-	-
	NA2	9	14.5	12.0	13.7	0.81
	MA2	4	14.6	11.3	13.3	1.45
Staghorn Sculpin	NA2	2	70.1	58.3	64.2	-
	MA2	3	63.9	38.9	54.9	13.9
Starry Flounder	NA2	1	31.0	-	-	-
	MA2	1	23.7	-	-	-

TABLE 4
DATA SUMMARY
CHLOROPHENOLS AND PCBs IN FISH MUSCLE

TRICHLOROPHENOL (ALL ISOMERS)			ug/g (dry/wet weight)			Dry Wt.
ND:0.001/0.0002	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	0.014/0.003	0.009/0.002	0.011/0.002	0.003
	NA2	17	0.057/0.011	ND	0.012/0.002	0.018
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	0.022/0.004	0.009/0.002	0.013/0.003	0.005
	NA2	18	0.084/0.017	ND	0.038/0.007	0.025
	MA2	10	0.054/0.009	ND	-	-
Peamouth Chub	MS1	5	0.049/0.008	0.021/0.004	0.031/0.006	0.011
	NA2	12	ND	ND	ND	-
	MA2	7	ND	ND	ND	-
Redside Shiner	MS1	5	0.089/0.019	ND	0.038/0.009	0.045
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	4	0.035/0.004	0.007/0.002	0.028/0.004	0.014
	MA2	8	0.031/0.005	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-
TETRACHLOROPHENOL (ALL ISOMERS)						
ND : 0.001/0.0002						
Largescale Sucker	MS1	3	0.006/0.001	ND	-	-
	NA2	17	ND	ND	ND	-
	MA2	11	0.015/0.002	ND	-	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	0.033/0.006	ND	-	-
	MA2	10	0.076/0.013	ND	-	-
Peamouth Chub	MS1	5	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	7	ND	ND	ND	-
Redside Shiner	MS1	5	0.05/0.012	ND	-	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	0.015/0.003	ND	-	-
Starry Flounder	NA2	4	0.001/0.0001	ND	-	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 4 (CONTINUED)

PENTACHLOROPHENOL

ND:0.001/0.0002

	Site	n	ug/g (dry/wet weight) Max	Min	Mean	Dry Wt. Std Dev
Largescale Sucker	MS1	3	0.009/0.002	0.006/0.001	0.008/0.001	0.002
	NA2	17	0.015/0.003	ND	0.003/0.001	0.004
	MA2	11	0.012/0.002	ND	0.006/0.001	0.004
Northern Squawfish	MS1	6	0.022/0.004	0.005/0.001	0.010/0.002	0.006
	NA2	18	0.077/0.017	ND	0.011/0.002	0.018
	MA2	10	0.011/0.002	ND	0.004/0.001	0.004
Peamouth Chub	MS1	5	0.013/0.002	0.008/0.001	0.010/0.002	0.002
	NA2	12	0.009/0.002	ND	0.003/0.001	0.002
	MA2	7	0.006/0.001	ND	-	-
Redside Shiner	MS1	5	0.053/0.012	ND	0.019/0.004	0.021
Staghorn Sculpin	NA2	6	0.005/0.001	ND	0.003/0.0004	0.002
	MA2	6	0.006/0.001	0.002/0.0003	0.004/0.001	0.002
Starry Flounder	NA2	4	0.003/0.001	ND	-	-
	MA2	8	0.015/0.002	0.003/0.0005	0.007/0.001	0.004
Threespine Stickleback	NA2	2	ND	ND	ND	-

POLYCHLORINATED BIPHENYLS (ALL AROCLORS)

ND : 0.005/0.001

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	0.078/0.015	0.038/0.007	0.06/0.01	0.02
	NA2	16	1.3/0.26	ND	0.20/0.04	0.31
	MA2	9	0.17/0.03	0.025/0.005	0.08/0.02	0.05
Northern Squawfish	MS1	6	0.38/0.07	0.045/0.008	0.21/0.04	0.13
	NA2	17	0.30/0.06	0.04/0.01	0.14/0.03	0.07
	MA2	12	0.34/0.06	0.076/0.014	0.17/0.03	0.07
Peamouth Chub	MS1	4	0.10/0.02	0.063/0.011	0.08/0.02	0.02
	NA2	12	0.16/0.03	0.069/0.02	0.10/0.02	0.03
	MA2	8	0.32/0.06	0.10/0.018	0.18/0.03	0.09
Redside Shiner	MS1	8	0.55/0.12	0.13/0.029	0.25/0.06	0.18
Staghorn Sculpin	NA2	6	0.10/0.02	ND	-	-
	MA2	6	0.22/0.04	0.078/0.015	0.14/0.025	0.06
Starry Flounder	NA2	3	0.27/0.03	0.078/0.02	0.17/0.03	0.10
	MA2	8	0.31/0.05	0.017/0.003	0.14/0.02	0.10
Threespine Stickleback	NA2	2	0.18/0.03	0.12/0.02	-	-

TABLE 5
DATA SUMMARY
CHLOROPHENOLS AND PCBs IN FISH LIVERS

TRICHLOROPHENOL (ALL ISOMERS) ug/g (wet weight)

ND : 0.025	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	0.094	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TETRACHLOROPHENOL (ALL ISOMERS)

ND : 0.025						
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	0.038	ND	-	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.028	ND	-	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	0.89	ND	0.321	0.493
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 5 (CONTINUED)

PENTACHLOROPHENOL
ND : 0.025

ug/g (wet weight)

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	0.027	ND	-	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.090	ND	-	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	0.30	ND	-	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

POLYCHLORINATED BIPHENYLS
ND : 0.050

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	0.35	0.11	0.222	0.094
	MA2	4	0.23	ND	0.105	0.086
Northern Squawfish	MS1	2	0.28	0.10	0.19	0.127
	NA2	8	0.64	0.085	0.252	0.181
	MA2	4	0.15	ND	0.083	0.047
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	1.09	0.17	0.506	0.256
	MA2	4	0.17	ND	-	-
Staghorn Sculpin	NA2	2	0.49	0.28	0.39	-
	MA2	3	0.14	0.10	0.12	0.02
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	0.52	-	-	-

TABLE 6
DATA SUMMARY
PHTHALATE ESTERS IN FISH MUSCLE

DIMETHYL			ug/g (dry/wet weight)			Dry Wt. Std Dev
ND : 0.05/0.01	Site	n	Max	Min	Mean	
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	17	0.48/0.09	ND	-	-
	MA2	12	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	0.94/0.18	ND	-	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	0.41/0.07	ND	-	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	1.2/0.21	0.70/0.12	0.95/0.17	-
DIETHYL						
ND : 0.02/0.004						
Largescale Sucker	MS1	4	1.06/0.21	ND	-	-
	NA2	16	1.90/0.37	ND	0.89/0.17	0.78
	MA2	9	5.82/1.15	1.54/0.31	3.21/0.60	1.66
Northern Squawfish	MS1	6	2.37/0.42	ND	-	-
	NA2	17	2.3/0.46	0.36/0.07	1.36/0.29	0.58
	MA2	12	4.39/0.76	ND	1.23/0.23	1.42
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	2.0/0.37	0.78/0.20	1.41/0.30	0.41
	MA2	8	2.4/0.43	ND	1.22/0.23	1.01
Redside Shiner	MS1	8	0.33/0.07	ND	-	-
Staghorn Sculpin	NA2	6	2.0/0.41	ND	1.22/0.21	0.83
	MA2	6	2.76/0.46	ND	1.41/0.24	1.14
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	1.85/0.31	0.30/0.0.05	0.85/0.14	0.48
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 6 (CONTINUED)

DI-N-BUTYL			ug/g (dry/wet weight)			Dry Wt.
ND : 0.02/0.004	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	0.93/0.18	0.078/0.02	0.36/0.07	0.39
	NA2	16	2.00/0.39	0.27/0.05	0.64/0.12	0.35
	MA2	9	0.40/0.07	ND	0.23/0.04	0.14
Northern Squawfish	MS1	6	1.15/0.21	0.03/0.005	0.51/0.09	0.47
	NA2	17	0.83/0.17	0.17/0.038	0.38/0.08	0.18
	MA2	12	1.15/0.20	ND	0.30/0.06	0.41
Peamouth Chub	MS1	4	1.39/0.22	0.24/0.04	0.85/0.15	0.57
	NA2	12	1.5/0.28	ND	0.30/0.06	0.30
	MA2	8	1.34/0.28	0.14/0.03	0.42/0.08	0.38
Redside Shiner	MS1	8	0.64/0.14	0.13/0.03	0.40/0.09	0.18
Staghorn Sculpin	NA2	6	1.10/0.20	0.058/0.01	0.53/0.09	0.39
	MA2	6	2.73/0.50	ND	0.88/0.15	1.22
Starry Flounder	NA2	3	0.56/0.13	0.33/0.04	0.43/0.07	0.12
	MA2	8	0.64/0.10	0.13/0.02	0.39/0.06	0.22
Threespine Stickleback	NA2	2	0.66/0.11	0.22/0.04	0.44/0.07	-
BUTYL BENZYL						
ND : 0.02/0.004						
Largescale Sucker	MS1	4	0.45/0.09	0.19/0.04	0.31/0.06	0.13
	NA2	16	0.25/0.05	ND	0.11/0.02	0.07
	MA2	9	0.19/0.03	0.034/0.007	0.09/0.02	0.05
Northern Squawfish	MS1	6	0.65/0.12	0.042/0.008	0.31/0.06	0.20
	NA2	17	0.37/0.08	0.066/0.012	0.19/0.04	0.09
	MA2	12	0.26/0.04	ND	0.14/0.03	0.08
Peamouth Chub	MS1	4	0.60/0.10	0.30/0.05	0.41/0.07	0.13
	NA2	12	0.32/0.06	ND	0.11/0.02	0.11
	MA2	8	0.57/0.12	0.055/0.01	0.19/0.04	0.16
Redside Shiner	MS1	8	0.43/0.09	0.17/0.04	0.30/0.07	0.09
Staghorn Sculpin	NA2	6	0.18/0.03	ND	0.07/0.01	0.057
	MA2	6	0.74/0.13	ND	0.23/0.04	0.27
Starry Flounder	NA2	3	0.27/0.03	0.16/0.02	0.21/0.03	0.056
	MA2	8	0.48/0.08	0.056/0.01	0.28/0.04	0.13
Threespine Stickleback	NA2	2	0.21/0.04	0.14/0.02	0.18/0.03	-

TABLE 6 (CONTINUED)

DI-N-OCTYL			ug/g (dry/wet weight)			Dry Wt.
ND : 0.05/0.01	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	0.21/0.04	ND	-	-
	NA2	16	0.092/0.019	ND	-	-
	MA2	9	0.18/0.035	ND	-	-
Northern Squawfish	MS1	6	0.97/0.18	ND	0.45/0.08	0.42
	NA2	17	0.90/0.18	ND	-	-
	MA2	12	0.11/0.02	ND	-	-
Peamouth Chub	MS1	4	0.63/0.11	0.07/0.01	0.24/0.04	0.28
	NA2	12	0.098/0.02	ND	-	-
	MA2	8	0.50/0.10	ND	-	-
Redside Shiner	MS1	8	0.74/0.18	ND	-	-
Staghorn Sculpin	NA2	6	0.23/0.04	ND	0.11/0.02	0.075
	MA2	6	0.63/0.12	ND	-	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	0.37/0.06	ND	-	-
Threespine Stickleback	NA2	2	2.1/0.36	1.6/0.28	1.9/0.32	-
BIS(2-ETHYLHEXYL) ND : 0.05/0.01						
Largescale Sucker	MS1	4	0.22/0.043	ND	-	-
	NA2	16	ND	ND	ND	-
	MA2	9	0.16/0.032	ND	ND	-
Northern Squawfish	MS1	6	1.58/0.29	0.16/0.03	0.51/0.09	0.53
	NA2	17	0.91/0.17	0.18/0.04	0.52/0.11	0.25
	MA2	12	0.69/0.12	ND	0.35/0.07	0.23
Peamouth Chub	MS1	4	1.06/0.22	0.35/0.05	0.64/0.12	0.30
	NA2	12	0.80/0.15	ND	0.31/0.06	0.29
	MA2	8	0.56/0.10	ND	0.26/0.05	0.17
Redside Shiner	MS1	8	1.32/0.29	ND	-	-
Staghorn Sculpin	NA2	6	0.72/0.12	0.28/0.05	0.50/0.09	0.19
	MA2	6	0.62/0.10	ND	-	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	0.64/0.10	ND	0.30/0.05	0.21
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 7
PHTHALATE ESTERS IN FISH LIVERS

DIMETHYL
ND : 0.5

	Site	n	ug/g (wet weight)			
			Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

DIETHYL
ND : 0.2

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	5.45	ND	2.64	1.75
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	1.52	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	6.57	ND	2.67	2.48
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	4.51	4.32	4.42	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 7 (CONTINUED)

DI-N-BUTYL
ND : 0.2

	Site	n	ug/g (wet weight)			
			Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	1.69	-	-	-
	NA2	6	1.48	ND	1.44	0.84
	MA2	4	1.86	0.65	1.23	0.66
Northern Squawfish	MS1	2	2.71	ND	-	-
	NA2	8	4.70	ND	1.80	1.47
	MA2	4	1.73	ND	0.88	0.80
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	1.95	ND	-	-
	MA2	4	2.10	ND	-	-
Staghorn Sculpin	NA2	2	0.21	ND	0.20	-
	MA2	3	9.39	ND	-	-
Starry Flounder	NA2	1	0.33	-	-	-
	MA2	1	1.00	-	-	-

BUTYL BENZYL
ND : 0.2

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.26	-	-	-
	NA2	6	1.45	0.34	0.69	0.42
	MA2	4	5.63	1.04	3.02	1.92
Northern Squawfish	MS1	2	0.38	ND	-	-
	NA2	8	2.70	0.60	1.13	0.71
	MA2	4	4.03	ND	1.79	1.89
Peamouth Chub	MS1	1	0.76	-	-	-
	NA2	9	0.53	ND	0.29	0.12
	MA2	4	0.57	0.20	0.39	0.16
Staghorn Sculpin	NA2	2	0.66	ND	0.43	-
	MA2	3	0.54	0.41	0.45	0.05
Starry Flounder	NA2	1	0.87	-	-	-
	MA2	1	0.58	-	-	-

TABLE 7 (CONTINUED)

DI-N-OCTYL
ND : 0.5

			ug/g (wet weight)			
	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	1.40	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

BIS (2-ETHYLHEXYL)
ND : 0.5

	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	3.83	-	-	-
Sucker	NA2	6	2.24	ND	0.93	0.70
	MA2	4	ND	ND	ND	-
Northern	MS1	2	1.39	0.50	0.95	-
Squawfish	NA2	8	2.35	ND	1.24	0.59
	MA2	4	1.95	ND	-	-
Peamouth	MS1	1	2.68	-	-	-
Chub	NA2	9	1.11	ND	-	-
	MA2	4	5.22	ND	2.68	1.99
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	4.71	1.15	2.70	1.82
Starry	NA2	1	0.84	-	-	-
Flounder	MA2	1	1.42	-	-	-

TABLE 8
DATA SUMMARY
POLYCYCLIC AROMATIC HYDROCARBONS IN FISH MUSCLE

ACENAPHTHENE			ug/g (dry/wet weight)			Dry Wt.
ND : 0.02/0.004	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	3	ND	ND	ND	-
Sucker	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn	NA2	5	ND	ND	ND	-
Sculpin	MA2	6	ND	ND	ND	-
Starry	NA2	3	ND	ND	ND	-
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	0.044/0.008	0.038/0.007	0.041/0.008	-
ACENAPHTHYLENE						
ND : 0.02/0.004						
Largescale	MS1	3	ND	ND	ND	-
Sucker	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn	NA2	5	ND	ND	ND	-
Sculpin	MA2	6	ND	ND	ND	-
Starry	NA2	3	ND	ND	ND	-
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

ANTHRACENE

ND : 0.02/0.004	Site	n	ug/g (dry/wet weight)			Dry Wt.
			Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

BENZO(A)ANTHRACENE

ND : 0.05/0.01	Site	n	Max	Min	Mean	Dry Wt. Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

BENZO(A)PYRENE ND : 0.1/0.02	Site	n	ug/g (dry/wet weight) Max	Min	Mean	Dry Wt. Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-
BENZO(B)FLUORANTHENE ND : 0.1/0.02						
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

BENZO(GHI) PERYLENE			ug/g (dry/wet weight)			Dry Wt.
ND : 0.1/0.02	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

BENZO(K)FLUORANTHENE						
ND : 0.1/0.02						
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

CHRYSENE			ug/g (dry/wet weight)			Dry Wt.
ND : 0.05/0.01	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-
DIBENZO(AH)ANTHRACENE						
ND : 0.1/0.02						
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

FLUORANTHENE			ug/g (dry/wet weight)			Dry Wt.
ND : 0.05/0.01	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	0.11/0.01	ND	0.08/0.01	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	0.066/0.011	0.058/0.010	0.062/0.010	-
FLUORENE						
ND : 0.02/0.004						
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	-	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

INDENO(1,2,3-CD) PYRENE			ug/g (dry/wet weight)			Dry Wt.
ND : 0.1/0.02	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

NAPHTHALENE						
ND : 0.02/0.004						
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 8 (CONTINUED)

PHENANTHRENE
ND: 0.02/0.004

			ug/g (dry/wet weight)			Dry Wt.
	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	0.10/0.02	ND	-	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	0.15/0.02	ND	0.08/0.01	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	0.15/0.026	0.11/0.019	0.13/0.0.022	-

PYRENE
ND : 0.05/0.01

	Site	n	Max	Min	Mean	Dry Wt. Std Dev
Largescale Sucker	MS1	3	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	11	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	18	ND	ND	ND	-
	MA2	10	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	13	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	7	ND	ND	ND	-
Staghorn Sculpin	NA2	5	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 9
DATA SUMMARY
POLYCYCLIC AROMATIC HYDROCARBONS IN FISH LIVERS

ACENAPHTHENE			ug/g (wet weight)			
ND : 0.02	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	0.035	ND	-	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	0.027	ND	-	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

ACENAPHTHYLENE ND : 0.02

Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	0.022	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	0.046	ND	-	-
	MA2	4	0.024	ND	0.022	0.002
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	0.032	ND	0.024	0.007
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	0.081	-	-	-

TABLE 9 (CONTINUED)

ANTHRACENE ND : 0.02

	Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	0.020	ND	-	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

BENZO (A) ANTHRACENE ND : 0.05

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	0.035	ND	-	-
Peamouth Chub	MS1	1	0.093	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 9 (CONTINUED)

BENZO (A) PYRENE ND : 0.1

			ug/g (wet weight)			
	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

BENZO (B) FLUORANTHENE ND : 0.1

	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	0.1	ND	-	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

TABLE 9 (CONTINUED)

BENZO (GHI) PERYLENE

			ug/g (wet weight)			
ND : 0.1	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

BENZO (K) FLUORANTHENE ND : 0.1

Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 9 (CONTINUED)

CHRYSENE ND : 0.05

			ug/g (wet weight)			
	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	0.077	ND	0.057	0.013
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

DIBENZO (A,H) ANTHRACENE ND : 0.1

Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

TABLE 9 (CONTINUED)

FLUORANTHENE ND : 0.05

			ug/g (wet weight)			
	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

FLUORENE ND : 0.02

Largescale	MS1	1	0.020	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	0.046	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	0.022	ND	-	-
	MA2	4	0.024	ND	0.021	0.002
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	0.067	ND	0.036	0.027
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	0.048	-	-	-

TABLE 9 (CONTINUED)

INDENO (1,2,3=CD)PYRENE

			ug/g (wet weight)			
ND : 0.1	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	0.12	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

NAPHTHALENE ND : 0.02

Largescale	MS1	1	0.074	-	-	-
Sucker	NA2	6	0.070	ND	0.033	0.019
	MA2	4	0.074	0.025	0.051	0.022
Northern	MS1	2	0.097	0.020	0.059	-
Squawfish	NA2	8	0.23	ND	0.079	0.069
	MA2	4	0.098	0.025	0.064	0.033
Peamouth	MS1	1	0.16	-	-	-
Chub	NA2	9	0.14	0.035	0.064	0.034
	MA2	4	0.10	0.025	0.059	0.031
Staghorn	NA2	2	0.020	ND	-	-
Sculpin	MA2	3	0.095	0.028	0.054	0.036
Starry	NA2	1	0.070	-	-	-
Flounder	MA2	1	0.12	-	-	-

TABLE 9 (CONTINUED)

PHENANTHRENE ND : 0.02	Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
Largescale	MS1	1	0.025	-	-	-
Sucker	NA2	6	0.020	ND	-	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	0.033	ND	-	-
Squawfish	NA2	8	0.034	ND	0.024	0.006
	MA2	4	0.023	ND	-	-
Peamouth	MS1	1	0.060	-	-	-
Chub	NA2	9	0.043	ND	-	-
	MA2	4	0.050	0.011	0.027	0.017
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	0.038	ND	0.027	0.009
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	0.071	-	-	-

PYRENE ND : 0.05						
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	0.09	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	0.070	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	0.12	ND	-	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

TABLE 10
DATA SUMMARY
ORGANOCHLORINE PESTICIDES IN FISH MUSCLE

ALDRIN			ng/g (dry/wet weight)			Dry Wt.
ND : 1.0/0.2	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	4	ND	ND	ND	-
Sucker	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn	NA2	6	ND	ND	ND	-
Sculpin	MA2	6	ND	ND	ND	-
Starry	NA2	3	ND	ND	ND	-
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-
ALPHA-CHLORDANE						
ND : 1.0/0.2						
Largescale	MS1	4	ND	ND	ND	-
Sucker	NA2	16	6/1.22	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	17	ND	ND	ND	-
	MA2	12	7/1.23	ND	2.75/0.51	2.14
Peamouth	MS1	4	3/0.62	ND	-	-
Chub	NA2	12	6/1.34	ND	3.3/0.70	3.06
	MA2	8	7/1.34	ND	-	-
Redside Shiner	MS1	8	2/0.48	ND	-	-
Staghorn	NA2	6	13/2.33	ND	-	-
Sculpin	MA2	6	6/1.10	ND	-	-
Starry	NA2	3	3/0.7	ND	-	-
Flounder	MA2	8	7/1.15	ND	3.38/0.55	2.20
Threespine Stickleback	NA2	2	4/0.7	4/0.7	4/0.7	-

TABLE 10 (CONTINUED)

GAMMA-CHLORDANE			ng/g (dry/wet weight)			Dry Wt.
ND : 1.0/0.2	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	8/1.50	ND	-	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	10/1.79	ND	-	-
	NA2	17	8/1.77	ND	-	-
	MA2	12	7/1.23	ND	-	-
Peamouth Chub	MS1	4	2/0.42	ND	-	-
	NA2	12	8/1.49	ND	-	-
	MA2	8	6/1.09	ND	-	-
Redside Shiner	MS1	8	4/0.87	ND	-	-
Staghorn Sculpin	NA2	6	9/1.52	ND	-	-
	MA2	6	8/1.46	ND	-	-
Starry Flounder	NA2	3	7/1.6	ND	3.7/0.6	3
	MA2	8	17/0.03	ND	8.25/1.34	5.80
Threespine Stickleback	NA2	2	ND	ND	ND	-
DIELDRIN						
ND : 1.0/0.2						
Largescale Sucker	MS1	4	5/0.95	ND	-	-
	NA2	16	11/2.10	ND	-	-
	MA2	9	7/1.42	ND	3.78/0.706	2.68
Northern Squawfish	MS1	6	5/0.91	ND	-	-
	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	4/0.85	ND	-	-
	MA2	8	8/1.53	ND	-	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	4.0/0.5	ND	2.0/0.4	1.5
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	8.0/1.0	5.0/1.0	6.5/1.0	-

TABLE 10 (CONTINUED)

DDT

ND : 1.0/0.2	Site	n	ng/g (dry/wet weight) Max	Min	Mean	Dry Wt. Std Dev
Largescale Sucker	MS1	4	6/1.13	ND	-	-
	NA2	16	5/0.96	ND	-	-
	MA2	9	14/2.59	ND	3.89/0.73	4.31
Northern Squawfish	MS1	6	1/0.187	ND	-	-
	NA2	17	ND	ND	ND	-
	MA2	12	2/0.356	ND	-	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	8	2/0.364	ND	-	-
Redside Shiner	MS1	8	1/0.224	ND	-	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	9/1.69	ND	3.8/0.66	3.66
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	3/0.49	ND	-	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

DDD

ND : 1.0/0.2	Site	n	Max	Min	Mean	Dry Wt. Std Dev
Largescale Sucker	MS1	4	6/1.13	ND	3.5/0.68	2.89
	NA2	16	25/5	ND	-	-
	MA2	9	19/3.55	ND	-	-
Northern Squawfish	MS1	6	26/4.65	ND	-	-
	NA2	17	36/6.98	ND	13.1/2.58	11.1
	MA2	12	11/2.44	ND	-	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	8	38/7.90	ND	15.5/2.98	14.9
Redside Shiner	MS1	8	43/0.094	ND	-	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	12/1.98	ND	-	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	15/2.46	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 10 (CONTINUED)

DDE			ng/g (dry/wet weight)			Dry Wt.
ND: 0.5/0.1	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	19/3.93	ND	-	-
	MA2	9	20/3.86	ND	8.06/1.51	6.69
Northern Squawfish	MS1	6	72/13.5	8/1.5	59.5/10.9	72.2
	NA2	17	97/18.4	19/4.20	41.1/8.10	25.5
	MA2	12	40/7.0	8/1.42	20.1/3.74	10.5
Peamouth Chub	MS1	4	17/2.92	14/2.20	15.3/2.73	1.50
	NA2	12	ND	ND	ND	-
	MA2	8	41/8.28	5/0.935	24/4.61	12.0
Redside Shiner	MS1	8	120/26.2	ND	44.4/9.98	26.1
Staghorn Sculpin	NA2	6	17/2.58	6/1.07	10.5/1.83	3.83
	MA2	6	12/2.26	ND	9.5/1.64	2.43
Starry Flounder	NA2	3	12/1.5	6/1.4	8.3/1.35	3.21
	MA2	8	29/4.79	2/0.31	11.6/1.89	9.04
Threespine Stickleback	NA2	2	15/2.6	14/2.4	14.5/2.5	-
ENDRIN						
ND : 1.0/0.2						
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	7/1.06	ND	-	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	3/0.71	ND	-	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 10 (CONTINUED)

ENDOSULFAN I

			ng/g (dry/wet weight)			Dry Wt.
ND:0.5/0.1	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	3/0.59	ND	-	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	12	15/2.63	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	10/1.94	ND	4.42/0.92	3.91
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	12/1.82	ND	-	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

ENDOSULFAN 11

ND : 2.0/0.4						
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	17	ND	ND	ND	-
	MA2	12	3/0.666	ND	-	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	6/1.01	ND	-	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 10 (CONTINUED)

ENDOSULFAN SULFATE			ng/g (dry/wet weight)			Dry Wt.
ND : 10.0/2.0	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	4	ND	ND	ND	-
Sucker	NA2	16	ND	ND	ND	-
	MA2		ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn	NA2	6	ND	ND	ND	-
Sculpin	MA2	6	10/1.88	ND	-	-
Starry	NA2	3	ND	ND	ND	-
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-
HEPTACHLOR						
ND : 1.0/0.2						
Largescale	MS1	4	ND	ND	ND	-
Sucker	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn	NA2	6	ND	ND	ND	-
Sculpin	MA2	6	ND	ND	ND	-
Starry	NA2	3	ND	ND	ND	-
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 10 (CONTINUED)

HEPTACHLOR EPOXIDE			ng/g (dry/wet weight)			Dry Wt.
ND : 10.0/2.0	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	17	6/1.2	ND	-	-
	MA2	12	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

LINDANE						
ND : 0.5/0.1						
Largescale Sucker	MS1	4	ND	ND	ND	-
	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern Squawfish	MS1	6	ND	ND	ND	-
	NA2	17	2/0.44	ND	-	-
	MA2	12	ND	ND	ND	-
Peamouth Chub	MS1	4	ND	ND	ND	-
	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn Sculpin	NA2	6	ND	ND	ND	-
	MA2	6	ND	ND	ND	-
Starry Flounder	NA2	3	2/0.47	ND	-	-
	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 10 (CONTINUED)

METHOXYCHLOR			ng/g (dry/wet weight)			Dry Wt.
ND : 5.0/1.0	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	4	ND	ND	ND	-
Sucker	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	17	11/0.22	ND	-	-
	MA2	12	17/3.38	ND	-	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	19/4.26	ND	-	-
Staghorn	NA2	6	ND	ND	ND	-
Sculpin	MA2	6	ND	ND	ND	-
Starry	NA2	3	23/2.90	15/3.56	18/2.92	4.36
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-
TOXAPHENE						
ND : 50/10						
Largescale	MS1	4	ND	ND	ND	-
Sucker	NA2	16	ND	ND	ND	-
	MA2	9	ND	ND	ND	-
Northern	MS1	6	ND	ND	ND	-
Squawfish	NA2	17	ND	ND	ND	-
	MA2	12	ND	ND	ND	-
Peamouth	MS1	4	ND	ND	ND	-
Chub	NA2	12	ND	ND	ND	-
	MA2	8	ND	ND	ND	-
Redside Shiner	MS1	8	ND	ND	ND	-
Staghorn	NA2	6	ND	ND	ND	-
Sculpin	MA2	6	ND	ND	ND	-
Starry	NA2	3	ND	ND	ND	-
Flounder	MA2	8	ND	ND	ND	-
Threespine Stickleback	NA2	2	ND	ND	ND	-

TABLE 11
ORGANOCHLORINE PESTICIDES IN FISH LIVERS

ALDRIN
ND : 0.010

			ug/g (wet weight)			
	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

ALPHA-CHLORDANE
ND : 0.010

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	0.013	ND	-	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	0.022	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.016	ND	-	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 11 (CONTINUED)

GAMMA-CHLORDANE
ND : 0.010

	Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	0.018	ND	-	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	0.022	-	-	-

DIELDRIN
ND : 0.010

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.055	ND	0.029	0.019
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	0.029	ND	-	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 11 (CONTINUED)

DDT **ND : 0.010**	Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	0.013	ND	-	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.026	ND	-	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	0.021	ND	-	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	0.042	-	-	-

DDD **ND : 0.010**	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.023	-	-	-
	NA2	6	0.040	ND	0.019	0.012
	MA2	4	0.050	0.015	0.028	0.015
Northern Squawfish	MS1	2	0.015	ND	-	-
	NA2	8	0.027	ND	-	-
	MA2	4	0.020	ND	0.013	0.005
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	0.011	ND	-	-
	MA2	4	0.023	0.020	0.022	0.002
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	0.022	ND	0.014	0.007
Starry Flounder	NA2	1	0.012	-	-	-
	MA2	1	0.044	-	-	-

TABLE 11 (CONTINUED)

DDE
ND : 0.005

	Site	n	ug/g (wet weight) Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	0.017	-	-	-
	NA2	6	0.067	ND	0.035	0.023
	MA2	4	0.031	0.022	0.026	0.004
Northern Squawfish	MS1	2	0.045	0.031	0.038	-
	NA2	8	0.16	0.03	0.074	0.043
	MA2	4	0.074	0.026	0.044	0.021
Peamouth Chub	MS1	1	0.050	-	-	-
	NA2	9	0.16	ND	-	-
	MA2	4	0.072	0.061	0.067	0.006
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	0.034	0.022	0.028	0.006
Starry Flounder	NA2	1	0.019	-	-	-
	MA2	1	0.025	-	-	-

ENDRIN
ND : 0.010

	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	0.019	-	-	-

TABLE 11 (CONTINUED)

ENDOSULFAN 1			ug/g (wet weight)			
ND : 0.005	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	0.018	ND	-	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	0.009	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	0.007	ND	-	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-
ENDOSULFAN II						
ND : 0.020						
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 11 (CONTINUED)

ENDOSULFAN SULFATE
ND : 0.10

	Site	n	Max	Min	Mean	Std Dev
			ug/g (wet weight)			
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

HEPTACHLOR
ND : 0.010

	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

TABLE 11 (CONTINUED)

HEPTACHLOR EPOXIDE			ug/g (wet weight)			
ND : 0.10	Site	n	Max	Min	Mean	Std Dev
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

LINDANE						
ND : 0.005						
Largescale Sucker	MS1	1	ND	-	-	-
	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern Squawfish	MS1	2	ND	ND	ND	-
	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth Chub	MS1	1	ND	-	-	-
	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn Sculpin	NA2	2	ND	ND	ND	-
	MA2	3	ND	ND	ND	-
Starry Flounder	NA2	1	ND	-	-	-
	MA2	1	ND	-	-	-

TABLE 11 (CONTINUED)

METHOXYCHLOR
ND : 0.050

	Site	n	Max	Min	Mean	Std Dev
			ug/g (wet weight)			
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-

TOXAPHENE
ND : 0.50

	Site	n	Max	Min	Mean	Std Dev
Largescale	MS1	1	ND	-	-	-
Sucker	NA2	6	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Northern	MS1	2	ND	ND	ND	-
Squawfish	NA2	8	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Peamouth	MS1	1	ND	-	-	-
Chub	NA2	9	ND	ND	ND	-
	MA2	4	ND	ND	ND	-
Staghorn	NA2	2	ND	ND	ND	-
Sculpin	MA2	3	ND	ND	ND	-
Starry	NA2	1	ND	-	-	-
Flounder	MA2	1	ND	-	-	-